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DEVELOPMENT OF A COMPUTER BASED AIR COMBAT MANEUVERING RANGE DEBRIEF SYSTEM INTERIM REPORT (VOLUME I)

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Volume I of this Interim Report presents an overview of the technical approach to ACMR debrief development, and a preliminary debrief design based on key training objectives and their associated aircrew task measures. The requirements for a computer based debrief system are discussed, together with the rationale for selection of an HP 45-T system. Preliminary data formats for key training objectives are presented. Finally, ACMR debrief software packages which are currently under development are identified and described. (Cont)

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The proposed debrief system is responsive to an operational requirement for both overall performance assessment and diagnostic appraisal. For this reason, we have chosen to call our debrief system the "Performance Assessment and Appraisal System (PAAS)."

Future plans are outlined, and center chiefly on the development of a demonstration system for ACMR debrief. Further development of criterion measures across remaining training objectives will be necessary to complete a final debrief design such that it represents a full treatment of "all aspect ACM" performance evaluation.

NAVTRAEQUIPCEN 78-C-0136-1

FOREWORD

The work reported here is part of the Human Factors Laboratory program to provide automated measurement of aircrew performance. Specifically, an automated system for debriefing air combat performance has been developed to provide feedback that: (1) indicates performance trends over time; (2) allows comparison of performance with various normative groups; (3) provides diagnostic results for individual aircrews; (4) formats results in ways to reduce unnecessary complexity for the instructor and to increase the ease of information processing by the student pilot; (5) relates specifically to training objectives, and (6) is provided more rapidly than currently possible. The preliminary version of the automated debrief has achieved operational acceptance. The companion volume to this report is, "A Problem Definition Study of U.S. Navy Air-to-Air Missile Envelope Recognition Training Interim Report (Volume II)." Both volumes are summarized in "Training Improvements for the Tactical Aircrew Training System (TACTS): Project Summary Report."

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PREFACE

Information presented in this Interim Report represents partial completion of the "ACMR Training Improvements Project," sponsored by NAVTRAEQUIPCEN under contract N61339-78-C-0136. The Interim Report has been divided into two separate volumes. Volume I, Development of a Computer Based ACMR Debrief System, is an unclassified report which describes the development and preliminary design for an ACMR debrief system. Volume II, A Problem Definition Study of U.S. Air-to-Air Missile Envelope Recognition Training, is a classified (Confidential) report which addresses current fleet practices and potential problem areas in missile envelope recognition training. In preparing the two volumes of this report we have chosen to use the familiar term "Air Combat Maneuvering Range (ACMR)" which has historically represented the Navy's terminology for the air combat instrumentation developed by Cubic Corporation Recently, the ACMR has been re-designated by COMNAVAIRSYSCOM (06E) as the "Tactical Aircrew Combat Training System (TACTS)." We will adhere to the new designation in future reports.

TABLE OF CONTENTS

LIST OF ILLUSTRATIONS

LIST OF TABLES

SECTION I
INTRODUCTION

Purpose

This section of the Interim Report discusses the development and preliminary design of a computer based ACMR debrief system. Such a system as currently envisioned will have the following applications:

1) It will serve as a vehicle to develop and test statistically summarized ACMR training data formats. Following the design and operational validation of candidate training data formats, selected formats may be incorporated on the ACMR Data Display System (DDS) for use in providing immediate diagnostic training feedback to operational aircrews.
2) It will serve as a baseline or prototype system designed to provide the requisite hardware and software components to store, process, retrieve and display cumulative performance trend data required for fleet personnel to evaluate progress in ACMR training.

Background

Dunlap and Associates, Inc. scientists have been involved in ACMR training and performance measurement for the past four and one-half years. Their on-site participation over this time period has been extensive. Over 300 air-to-air missions and post-mission debriefs have been observed to date. Observations made over the past few years have indicated that ACMR training missions and their associated debriefs vary considerably in training emphasis, and in the content and quality of information presented to aircrews under instruction.

Some of the more salient ACMR training problems observed during on-site participation with operational aircrews are briefly summarized below:

1) There is considerable variation in the type and quality of ongoing training and debrief practices.
2) There are no standardized training procedures or structured debrief aids available to fleet personnel, beyond the customary "operators manual" describing ACMR functions.
3) The ACMR data display formats, designed to present digital and graphic information depicting ACM engagement geometry, flight instrument, and weapon simulation data, are not optimized to provide summarized statistical information essential for immediate training feedback.
4) There is currently no user operated system for storing, analyzing, retrieving and displaying cumulative training data or trend analysis information required to evaluate ACMR training progress on a longitudinal basis.

In general, current ACMR debriefs have been found to be highly variable in content, unstandardized, and non-cumulative. ACMR performance results, as presently used, are not specifically related to training objectives nor are they given in a format easily understood by operational users.

Although ACMR presents an effective application of advanced instrumentation, computing, and display technology, it has yet to benefit from a concomittant application of state-of-the-art training methods. The development, design, and implementation of a computer based ACMR debrief system promises to improve substantially the utilization of ACMR as a training and performance assessment system. A systematic approach to ACMR training and performance assessment, exemplified by the proposed debrief system, will produce the required documentation and provide users with the necessary framework to accomplish their air combat training mission.

SECTION II

TECHNICAL APPROACH

Air Combat Maneuvering Range (ACMR)

The ACMR is a sophisticated training facility acquired by the Navy and now in use to train fighter aircrews in air-to-air combat. The system is designed to train aircrews in actual combat maneuvers and in recognition of weapon delivery boundaries. ACMR provides data display features which greatly enhance air combat debriefs, and provide a rich source of continuously recorded quantitative measures. Some of the capabilities of ACMR include the following:[1,2]

1) Real-time tracking of aircraft engaged in air combat training in a specified airspace,
2) Video tape playback of flight history data, complete with pictorial display of the air-to-air engagement and voice transmissions,
3) Both digital and graphic hard-copy printouts of flight instrument data, interaircraft positions, cockpit view of engaged aircraft, mission data, and
4) Computer generated estimates of weapon launch outcomes.

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[1]Brictson, C.A., Ciavarelli, A.P. and Jones, T.N. Development of Aircrew Performance Measures for the Air Combat Maneuvering Range (ACMR) (U). Pensacola, Florida: Naval Aerospace Medical Research Laboratory, Report No. L53001, June 1977. (CONFIDENTIAL)

[2]Brictson, C.A., Ciavarelli, A.P., Pettigrew, K.W. and Young, P.A. Performance Assessment Methods and Criteria for the Air Combat Maneuvering Range (ACMR): Missile Envelope Recognition (U). Pensacola, Florida: Naval Aerospace Medical Research Laboratory, Special Report No. 78-4, July 1978. (CONFIDENTIAL)

Training Design Elements

A thorough consideration to the rudiments of training design would consider such elements as:

1) ACMR training requirements analysis,
2) Specification of training objectives and their associated operational tasks,
3) Metnods of performance assessment,
4) Instructor selection and training,
5) Adversary pilot training,
6) Training data and display formats,
7) Training utilization guides which include a training syllabus, curriculum design and lesson plans, and
8) Training effectiveness evaluation techniques.

At the outset of our research and development program, we have sought to maintain our level of effort within manageable limits. The above underlined training design elements represent those which could be addressed during the development and design of a computer-based ACMR debrief system. The remaining training design elements, certainly no less important, can be added later as essential "building blocks" required to complete an overall systems approach to ACMR training design.

ACMR Training Requirements

The Air Combat Maneuvering Range was conceived and designed to meet the following operational training requirements:

1) Train aircrews in all aspects of ACM,
2) Provide information for training feedback during debriefing,
3) Provide quantitative measures of aircrew proficiency and combat readiness, and
4) Develop maximum ACM proficiency through effective ACMR use.

These requirements were derived and summarized from operational doctrine[3,4] in order to identify the overall training goals that the ACMR system was expected to accomplish. To determine how well ACMR meets these requirements additional analysis was necessary to more fully describe the ACMR system in terms of it's training and measurement capabilities.

ACMR System Components

For purposes of analysis and description the ACMR system was broken down into three broad categories: personnel, equipment and mission-related variables. Those categories were further divided into six major system components:

- Personnel
  - Aircrews
  - Instructors
- Equipment
  - Aircraft
  - Weapons
- Mission
  - Mission
  - Environment

Associated with each component are certain subsystem elements considered as potential sources of training performance variation. Table 1 lists the six major system components and the principal variables associated with each component.

The adequacy of ACMR training effectiveness and utilization will depend in large part upon understanding the relative influence and interactions of these variables on aircrew ACM performance. For example, ACM performance

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[3]Commander Operational Test and Evaluation Force. Operational Appraisal of the Air Combat Maneuvering Range. August 1974 (OPNAV 3930-11).

[4]Naval Air Systems Command, ACMR Evaluation Summary: AN/USQ-5[illegible]). August 1975, Report No. ACMR-I-1-75-1.

TABLE 1. ACMR TRAINING SYSTEM COMPONENTS AND DATA BANK TAXONOMY

Personnel		Equipment		Mission	
Instructors*	Aircrews	Aircraft	Weapons	Mission	Environment
• Experience and training	• Adversary and fighter aircrews	• Adversary and fighter type	• Type	• Type (e.g., single or multiple aircraft)	• Weather
• Inflight and debrief procedures and technique	• Perceptual/ motor skills	• Performance characteristics and limitations	• Design characteristics and limitations	• Specific training objectives	• Visibility
• Content and quality of directive commentary (related to RTO's)	• Training and education	• Specific design features	• Delivery parameters	• Tactics and maneuvers specified and/or used	• Terrain
• Training function and tasks	• Flight experience (total, type, crew, section)	• Particular weapon and sensor compliment	• Procedures	• Range operating constraints	• Traffic
• Training aids	• ACM experience	• System/subsystem operating status	• Specific weapon load and selection options	• Participating aircraft (mission mix)	• Sun
					• Misc.

*Including Range Training Officer (RTO) and Flight Leader.

is dependent on the prior experience and training of instructors and aircrews, type aircraft and weapon, and mission/environmental variables. Because ACM performance is influenced by various combinations of system components the description and breakdown presented in Table 1 is also useful as a data bank taxonomy and reference system. Each set of performance data collected on the ACMR system can be described and referenced by the system components identified in the table. ACM performance variations can thus be related to specific system components and, if desirable, systematically controlled in future training sequences to assess their relative influence on system performance. The identification, organization and analysis of ACMR variables in terms of system components provides the necessary framework for incorporating ACM performance assessment methodology into a computer-based debrief system.

ACMR Training Objectives

The Naval Fighter Weapons School (NAVFITWEPSCOL) located at Miramar NAS, California, is the primary source for development, instruction, and dissemination of Navy ACM tactical doctrine. Training emphasis at NAVFITWEPSCOL is placed on teaching advanced principles of air combat tactics to fleet experienced aircrews. As such, NAVFITWEPSCOL instruction provides a certain degree of commonality concerning the content of tactical doctrine and how ACM missions are conducted in the fleet.

Project personnel established contact at the NAVFITWEPSCOL in order to obtain the most recent information on Navy ACM instructional objectives. Members of the technical staff attended classroom training at NAVFITWEPSCOL, conducted interviews with NAVFITWEPSCOL instructors and reviewed Navy ACM tactical documents. An outgrowth of those activities was the identification and description of primary ACM(R) training objectives.

Thirteen ACMR training objectives were derived through analysis of the doctrinal information provided by NAVFITWEPSCOL. Those objectives and their corresponding narrative descriptions are presented in Table 2. Preliminary verification of the 13 ACMR training objectives, in terms of their completeness, descriptions, and application was accomplished by working sessions

TABLE 2. DESCRIPTION OF PRIMARY ACMR TRAINING OBJECTIVES

Training Objective*	Aircrew Task Description
1. Plan of Attack	Establish and implement an effective plan of attack, considering adversary capabilities, threat area, formation and fuel requirements.
2. Radar Procedures	Set up search pattern, i.e., beam coverage and scan technique, assign section responsibilities, and operate radar equipment to establish an early contact and to enter fight with best tactical advantage.
3. Look-Out Procedures	Utilize weapon system displays to gain early initial tally ho and maintain look-out responsibilities to keep sight of all adversaries and wingman.
4. Mutual Support	Provide mutual support by coordinating section maneuvers, communicating intentions and adversary position data, and protecting each other's vulnerable areas.
5. Section Tactics	Designate and maintain free fighter and engaged fighter responsibilities and coordinate fighter maneuvers to force adversary into a defensive position for a kill.
6. Tactics and Maneuvers	Use recommended offensive and defensive tactics to (1) maneuver fighter to adversary lethal zone, (2) warp envelope away from attacking adversary and neutralize adversary threat.
7. Energy Maintenance	Maintain energy level by entering fight with good energy package, unloading when possible, fighting fast with minimum arcing.
8. UHF Use	Use accurate and sufficient UHF commentary, including calls for radar status, contact, tally and visual, "six clear," adversary switches, position information and transmission of intentions.

*Training objectives itemized here are considered to be categories of task dimensions related to successful ACM performance.

TABLE 2. DESCRIPTION OF PRIMARY ACMR TRAINING OBJECTIVES (Cont)

Training Objective	Aircrew Task Description
9. Cockpit Coordination	Provide good cockpit coordination through analysis of threat, division of look-out responsibilities, and discretionary use of directive commentary.
10. Weapon Selection and Switchology	Select a weapon appropriate to tactical situation by projecting your anticipated aircraft position relative to adversary, planning the maneuvers required to reach the weapon envelope of your choice, and setting correct switches to fire weapon selected.
11. Envelope Recognition and Weapon Fire	Recognize weapon envelope and fire within recommended parameters such as range, angles off, pointing, closing velocity, and consider other relevant factors such as sun angle, wingman position, clutter, etc. to assure successful launch sequence.
12. Bugout Procedures	Disengage or bugout when required to meet projected fuel state limits and other possible tactical disadvantages which may seriously threaten survival.
13. Debriefing Procedures	Provide knowledge of results and diagnostic training feedback during debrief in regard to successful and/or unsuccessful completion of training objectives.

with fleet and NAVFITWEPSCOL personnel and through briefings with CNO, COMNAVAIRPAC, NAVFITWEPSCOL, Fleet Squadrons and COMFIT command officers.

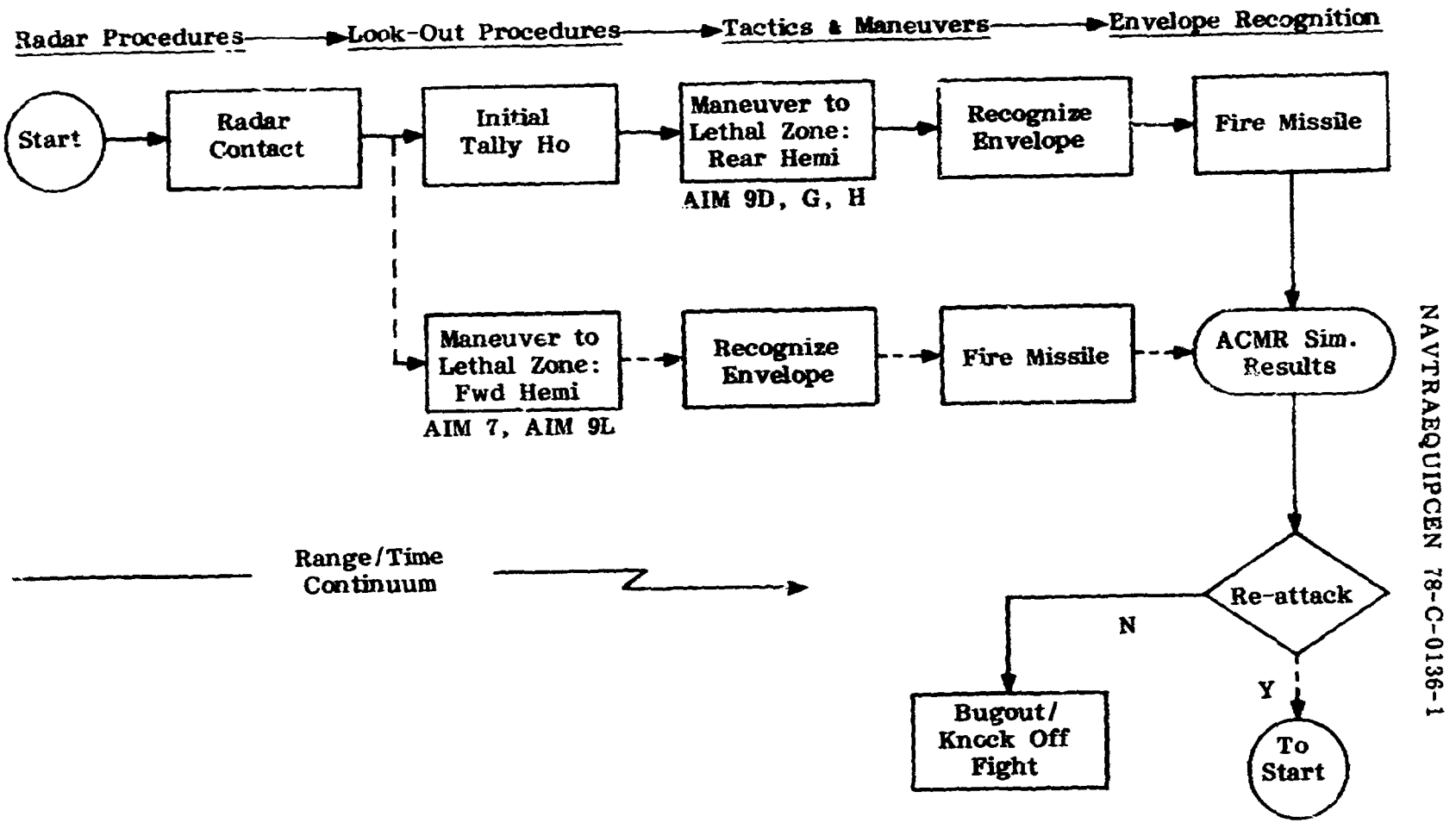
The identification of primary training objectives provided a useful frame of reference for structuring ACMR training operations and deriving candidate performance measures needed to assess aircrew task performance for key training objectives.

An analysis of training objectives and related aircrew tasks indicated that all of the itemized training objectives were not readily quantifiable, nor were the individual objectives of equal importance to ACM training. As part of the analysis, it was necessary to select certain objectives for quantitative evaluation on a priority basis. Training objectives selected for study met at least two requirements: 1) that the particular objective represent an important underlying task in ACM that can be taught using the range, and 2) that the critical task components associated with a particular objective be amenable to quantification, preferably through readily accessible ACMR output measures. The primary training objectives selected for evaluation during this particular phase of debrief development are itemized below: (see Table 2 descriptions)

- Radar Procedures
- Look-Out Procedures
- Tactics and Maneuvers
- Envelope Recognition

ACM Sequence

Figure 1 depicts a simplified ACMR operational sequence. The ACM sequence provides a framework for collection of ACMR in-flight performance measures at key points in an air combat engagement. As indicated in Figure 1, there is a correspondence between our four selected training objectives and specific points in the ACMR sequence. The points selected in the ACM sequence provide a rational analytic structure for recording, analyzing, and reporting training data for immediate debrief and for later review of performance trends.



NAVTRAEQUIPCEN 78-C-0136-1

Figure 1. ACMR Mission Sequence

Data Collection Requirements

Data collection procedures, as currently conducted, call for recording ACMR measures at radar contact, tally ho, time segment between tally ho and weapon release, and during missile fire. ACMR measures required at each point in the air combat sequence are specified in Table 3. Included in Table 3 is a listing of exercise and supplementary data required for describing mission related and background information.

Performance Assessment Methods Development

The emergence of ACMR, with its aircraft tracking and instrumentation capabilities, has provided a means to obtain continuously recorded inflight measures of system performance for incorporation to the ACMR debrief system. In order to use these quantitative outputs for aircrew training progress and proficiency evaluation they must be:

1) Statistically summarized and evaluated,
2) Qualified with respect to a particular combination of system components and operating conditions,
3) Related back to specific training objectives and their associated task elements, and
4) Compared with ACMR criteria or standards of performance.

Our technical approach provides the framework for assessing performance within the context of the training environment and across ACM variables of interest.

TABLE 3. PERFORMANCE MEASURES FOR SELECTED TRAINING OBJECTIVES

Radar Procedures	Look-Out Procedures	Tactics & Maneuvers	Envelope Recognition
• Time	• Time	• Time	• Missile Simulation Result
• Range	• Range	• Range (T)	• Time of Fox Call
• ALT Separation	• ALT Separation	• Mach vs Alt. *	• Time of Trigger Pulse
• Antenna Train Angle (ATA)	• Antenna Train Angle (ATA)	• Indicated Airspeed (IAS) vs Time*	• Time in or out of envelope
• Indicated Airspeed (IAS)	• Indicated Airspeed (IAS)	• Range (R)	• Range
• Target Aspect	• Target Aspect	• g vs Time*	• Angle Off Tail (AOT)
• Radar Opportunity	• Success Ratios	• Success Ratios	• Antenna Train Angle (ATA)
• Success Ratios	• Voice (UHF)	• Voice (UHF)	• Closing Velocity (Vc)
• Voice (UHF)		• Offensive, Neutral, and Defensive ACM States	• Indicated Airspeed (IAS)
			• g
			• Reason for Miss
			• Success Ratios
			• Voice (UHF)

*Time History Data

Note: A glossary of terms, including variable definitions, is provided in Appendix D.

TABLE 3. PERFORMANCE MEASURES FOR SELECTED TRAINING OBJECTIVES (Cont'd)

Exercise Data	Supplementary Data
• Type Mission and Mode	• Weapon Subsystems (SEAM, VTAS, etc.)
• ACMR Video Tape Number	• Weather/visibility
• ACMR Date/Time Code	• Range operating status/condition
• Squadron I.D. (Fighter)	• Aircraft/weapon system and operating status, condition
• Squadron I.D. (Adversary)	• Squadron background/aircrew experience
• Number and Type Aircraft, I.D.	• Preflight briefing and post-flight debrief content
• Range Training Officer (RTO)	• Aircrew voice calls, radar contact, tally ho, lost sights, fcx calls, etc.
• Flight Leader (FL)	• On-site observation notes all phases of training operations
• Aircrew I.D. (pilot, RIO)	
• Weapon load	

Types and Levels of Performance Criteria

In a previous technical report,[5] two levels of criterion measurement were discussed. Figure 2 illustrates this measurement approach. A first level criterion deals specifically with the terminal aspect of air combat given in terms of "engagement outcomes" (win, loss, and draw statistics). The use of engagement outcomes is important for evaluating which aircrew won or lost the air combat engagement.

A second criterion measurement level uses measures associated with "task accuracy" to assess aircrew performance. Task accuracy measures are based on interaircraft tracking data from ACMR. The importance of these measures is that they provide a wealth of information related to successful and unsuccessful aircrew task performance. Information regarding how a particular engagement was won or lost is provided in task accuracy measurement. Examples of task accuracy measures include continuously recorded range and angle-off-tail data during inflight ACM engagements. Assessment of aircrew proficiency in ACM entails the use of both engagement outcomes and task accuracy measures.

During the course of measurement research, relationships between task accuracy measures (2nd level criteria, or proximal measures) and engagement outcomes (1st level criteria, or distal measures) will be investigated. As an example, results from previous research have already established the following relationships:[5]

- Envelope recognition task accuracy scores, angle-off-tail, interaircraft range, and closing velocity, correlate highly with missile fire success (i.e., ACMR simulated "kill," "no kill" results).
- The likelihood for an initial visual acquisition (Tally Ho) increases with a successful radar contact.

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[5]Ciavarelli, A.P., Brictson, C.A. and Young, P.A. Development and Application of Performance Criteria and Aircrew Assessment Methods for the Air Combat Maneuvering Range (ACMR) (U). Special Report 79-5, Pensacola, Florida: Naval Aerospace Medical Research Laboratory, September 1979. (CONFIDENTIAL)

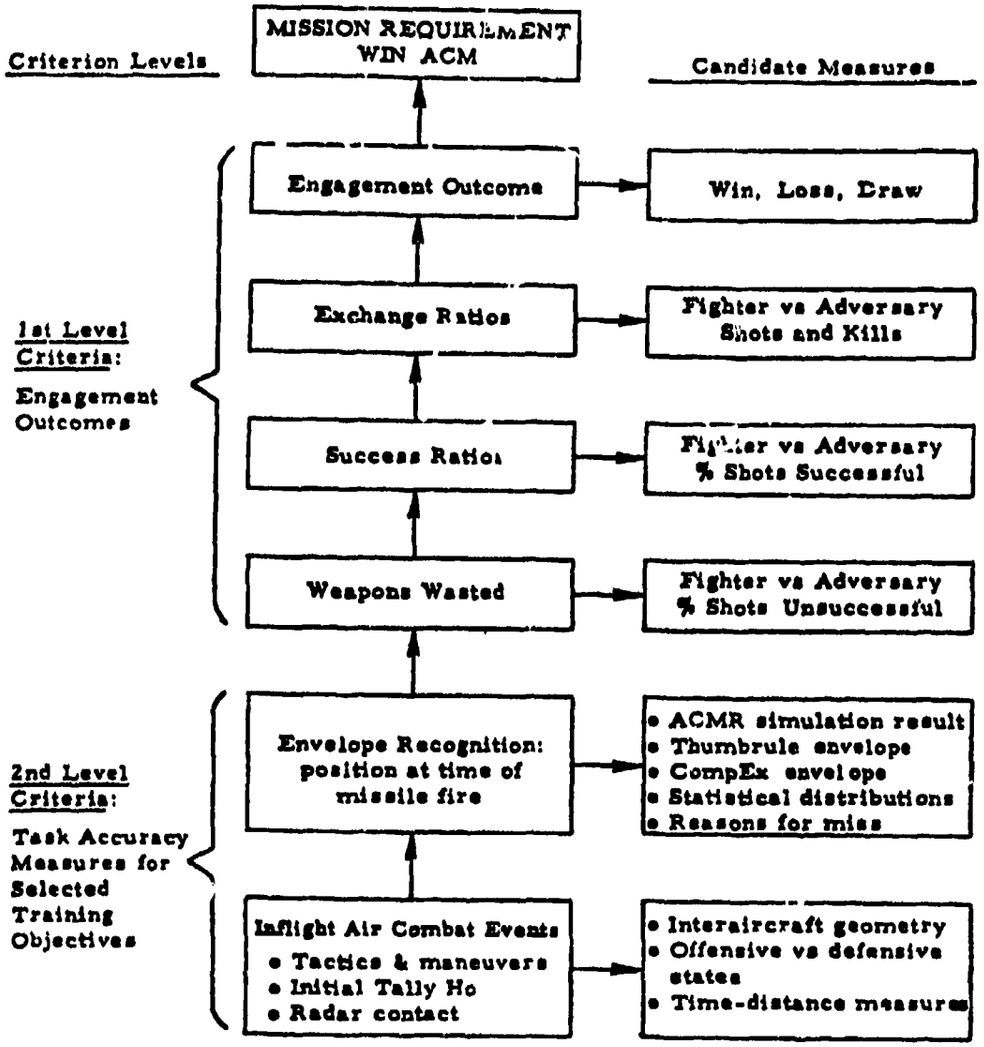

Figure 2. Criterion Levels and Candidate Measures

- Success on search and locate tasks (radar contact and tally ho) results in an increased likelihood of a 1st shot and 1st kill in a vectored air combat engagement.

Analyses and results such as those presented above represent a part of an overall research effort to validate the measures used as candidates for the debrief system.

Performance Criteria Standards

Candidate measures of air combat performance and assessment methods that are appropriate for debrief purposes will be selected from ongoing ACMR criterion research. Some important considerations in this selection process are discussed in this section.

ACMR field operational measures by themselves do not necessarily represent valid and reliable performance criteria. The researcher is still confronted with the unresolved question, "Which measures to use, and why?" Although ACMR provides a rich source of inflight quantitative measures, much remains to be done to select candidate measures which can be meaningfully related to successful performance of highly multidimensional air combat tasks. In addition, candidate ACMR measures must themselves meet stringent measurement standards prior to their application as performance criteria. Brodsky[6] presents a brief, but lucid, set of measurement standards, which are listed in an adapted form below:

> Validity. Measures will predict performance on a general set of tasks which contain the same or similar elements.
> Reliability. The obtained measures can be reproduced under the same or similar conditions.

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[6]Brodsky, M.A. The use of full scale mission simulation for the assessment of complex operator performance. Human Factors, 1967, 9(4), 341-348.

Sensitivity. Measures will discriminate, i.e., indicate changes in obtained performance with the application of a treatment.

Operational Utility. The use of a task measurement scheme will provide data which are applicable to predict performance on operational tasks.

To these standards we have added "user acceptance" and "data availability." A criterion should be understood and acceptable to operational users. By data availability, it is meant that data required for any criterion should be in sufficient quantity and readily available to allow for a sound statistical base, i.e., large samples and easy availability. The technical approach for ACMR criterion development considers these particular measurement standards, together with a systems orientation, as an essential framework for deriving viable air combat performance criteria for later incorporation into final debrief design.

Measurement Framework

Outputs from ongoing criterion research have been used to construct an integrated measurement framework consisting of measures of air combat success for selected training objectives and their associated task elements. Measures selected for final application in the ACMR debrief system will be those which satisfy requirements specified in the criterion research phase of development, e.g., reliability, validity.

The resulting measurement framework will address critical ACM tasks and acceptable standards of performance. For example, missile launch performance assessment can be established on the basis of doctrine missile boundaries, e.g., thumbrule envelopes, as an acceptable performance standard.

Summary and Discussion

The development and design of a computer-based ACMR debrief system will require at a minimum: 1) extensive knowledge of the air combat mission, 2) specification of ACMR training objectives and associated aircrew tasks, and 3) the development of reliable and valid performance criteria and aircrew assessment methods. The technical approach presented thus far considered each of these above factors. By and large, this initial conceptual framework has been applied during our previous research related to the development of ACMR performance criteria.[7]

This fundamental framework will serve also as a point of departure and initial foundation for a proposed ACMR debrief system. The following sections in Volume I of this interim report will deal directly with the functional requirements for the preliminary ACMR debrief system, beginning with the current manual debrief procedures (a baseline system) and ending with the preliminary design features of an automated debrief package (a computer-based system).

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[7]See footnote 5, page 19.

SECTION III

DEBRIEF DEVELOPMENT AND PRELIMINARY DESIGN

The Manual System: Data Collection and Analysis

System Functions. Certain functions have to be performed in order to obtain meaningful ACMR data, whether automation is available or not. Seven generic functions are itemized below, followed by a description of how each of these functions is performed on the manual, or baseline, system.[8]

1) Observation
2) Extraction
3) Transcription
4) Processing
5) Analysis
6) Review
7) Report

Observation. On-site observation of ongoing ACMR training has been, and will continue to be, an essential requirement of ensuring the quality of performance data obtained. In some instances the need for a trained observer is mandatory. For example, radar contact and tally ho data can only be obtained through monitoring voice communications during ACMR replay. In addition, presence during live flights and aircrew debriefings is required to: 1) describe and define ACMR operating conditions, 2) qualify unique circumstances and events, 3) edit and remove potential bias and contamination in source data, and in general, to understand the overall operating environment in which data collection has occurred. Quite simply, there is no replacement for the trained human observer in performing this function.

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[8]Ciavarelli, Anthony Evaluation of the Readiness Estimation System (RES) for ACMR Data Extraction and Analysis. La Jolla, CA: Dunlap and Associates, Inc. March 1979. (Prepared for Naval Aerospace Medical Research Laboratory, Contract No. N00612-78-C-8007.)

Extraction. In the manual data collection and analysis system, data are extracted from the ACMR display system through use of the hardcopy printer. Content of the data collected, therefore, is limited to the formats available on the ACMR Display and Debrief System (DDS). Other sources of potentially useful data, such as time history measures, and "in" envelope indications are not available for analysis in the present manual system.

Transcription. ACMR raw data outputs from the DDS require further transcription to an analytic framework which includes organization of the data by squadron or unit, aircrews, aircraft types, weapon types, engagement and weapon fire events, and other pertinent categories. This analytic framework serves as the basic ACMR performance data matrix used in further statistical analysis. At this time, data entry to this framework is a manual process.

Processing. Data from the basic matrix are coded and keypunched for subsequent computer processing. Once data are on IBM cards, efficient use of computer-based statistical and analytic programs is possible.

Analysis. Summarized statistical data, after computer processing, are reviewed by scientists at Dunlap and Associates, Inc. and performance trends are studied. In some cases further analysis is required. Knowledge of air combat tactics, and fleet training doctrine is essential for interpreting results and for transforming the highly technical statistical findings into operationally meaningful data formats.

Review. A review period is allowed prior to final reporting in order to interact with operational personnel regarding the implications of significant air combat performance trends. Interaction with experts in the operational community has been an indispensable aid toward interpreting variations in aircrew performance observed.

Report. Data collection procedures, performance assessment methods, and results from analysis of air combat performance usually have been documented as a final research report.

The manual, or baseline, system for ACMR data extraction and analysis is schematically presented in Figure 3. With exception of statistical data processing accomplished with computer assisted techniques, the system currently used is entirely manual.

The following section of this document presents a description of an automated data retrieval system, which is proposed as a candidate system for more efficient data extraction and analysis necessary for immediate training feedback.

An Automated System: Data Collection and Analysis

An important consideration in the final design of an ACMR debrief system will be the development of automated ACMR data extraction methods.[9] Figure 4 depicts a proposed conceptual design for an automated ACMR data extraction system. The system proposed will be designed to extract data in a format tailored to specific performance measurement requirements and to fullfill the need to present timely information for immediate training feedback to aircrews under instruction.

As currently envisioned, the retrieval system design will be based on the use of a special purpose disk which will serve to call, display, and print ACMR data in a prescribed format. The retrieval system will be operated during or immediately after post-mission debrief in order to edit ACMR data with pertinent debrief information. In this manner summarized statistical data related to task performance in air combat will be readily available to aircrews with hardcopy print-outs serving to document results of the ACMR missions observed. Performance data obtained as hardcopy results can be further transcribed and analyzed off-line in order to study ACMR performance trends over time and repeated engagements.

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[9]As proposed in "Development of a Performance Measurement and Assessment System for ACMR" (unsolicited technical proposal) prepared for the Naval Aerospace Medical Research Laboratory, Pensacola, Florida, May 1979.

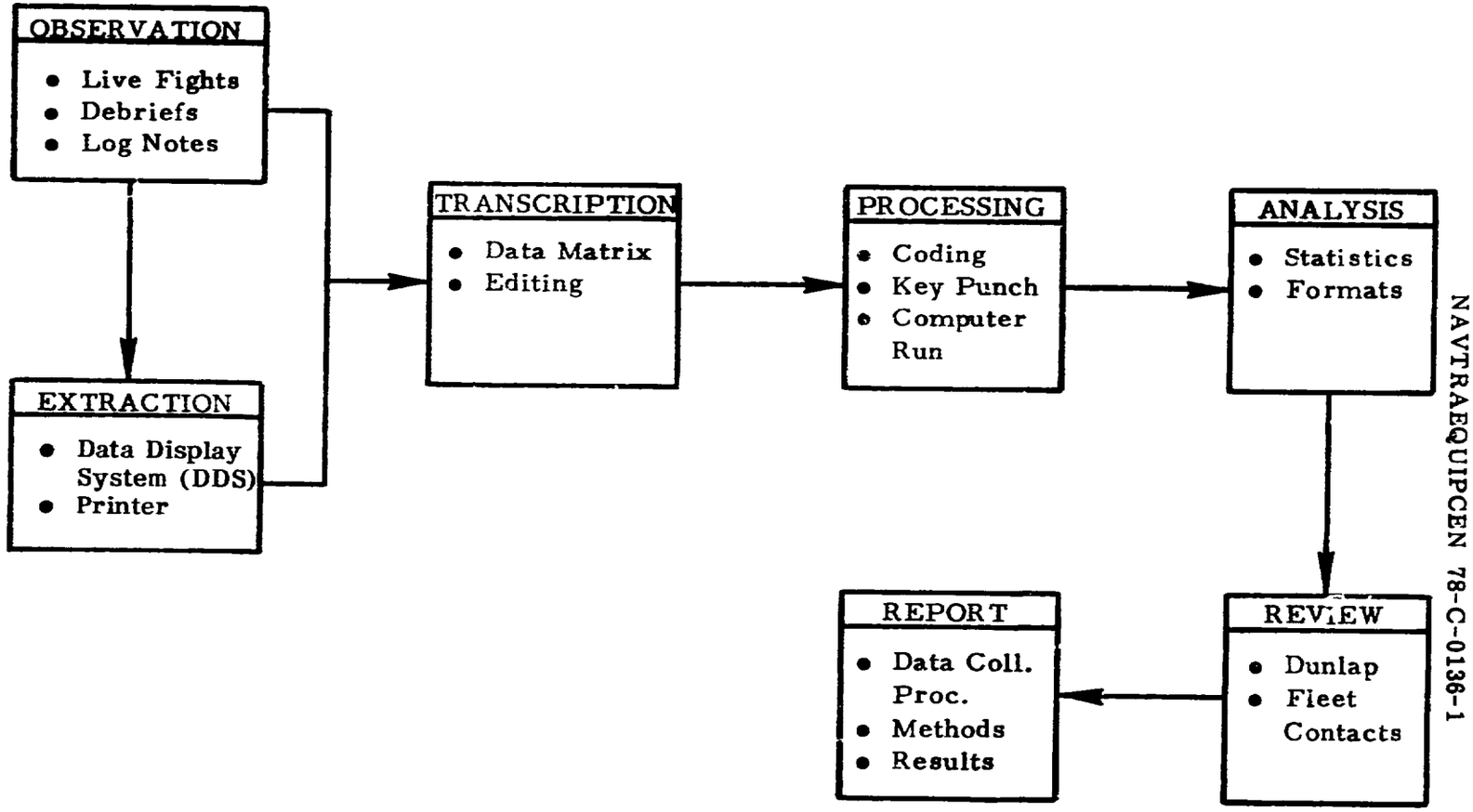

Figure 3. Flow Chart Dipicting ACMR Data Collection and Analysis Functions

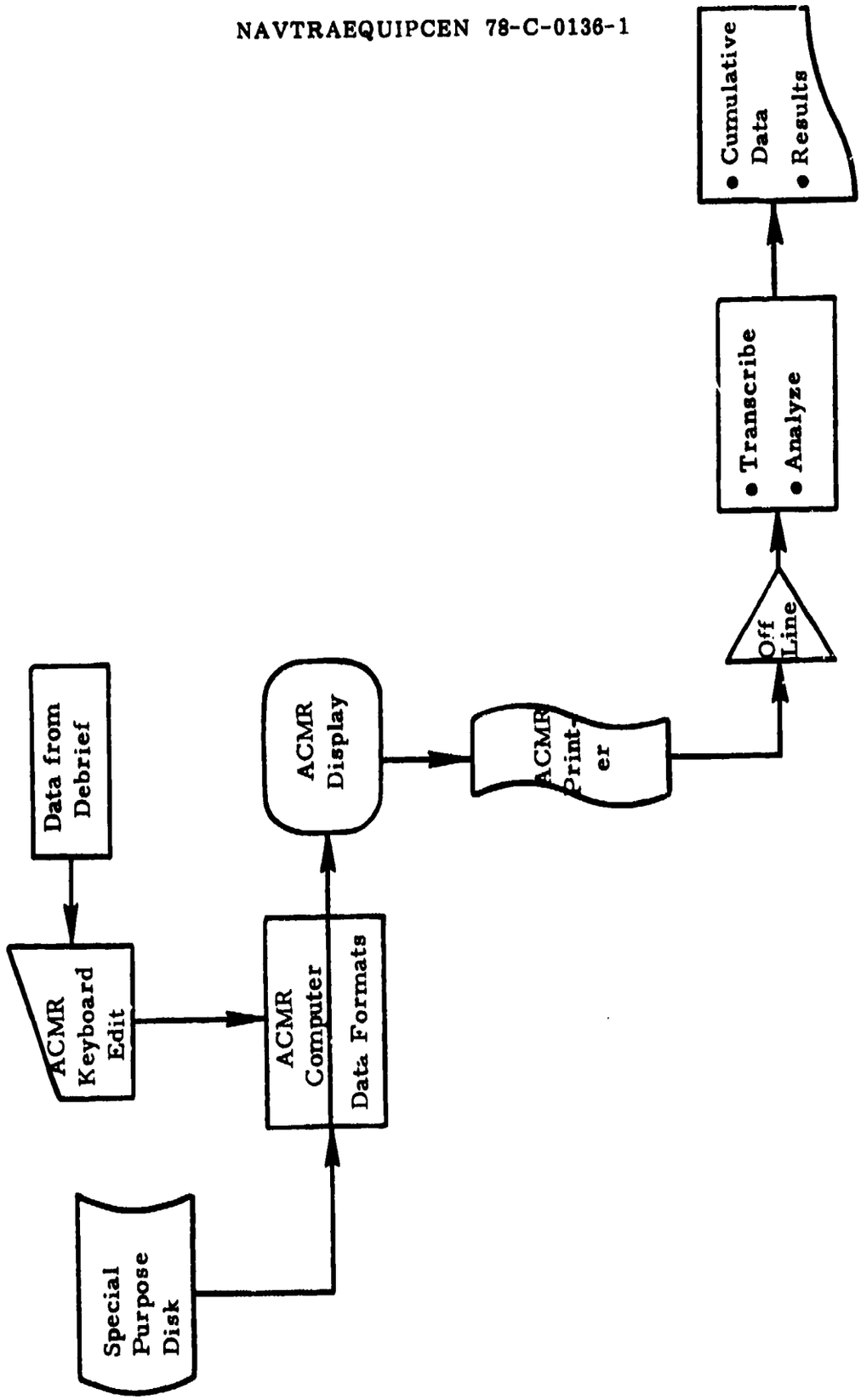

Figure 4. Schematic Representation of Proposed ACMR Retrieval System

Long-range plans for more efficient retrieval and analysis of ACMR data call for additional hardware interface which would allow a direct transcription of ACMR data to an output device (i.e., magnetic tape or disk). Having data in an appropriate output form will greatly facilitate off-line data processing without the intermediate step of manual transcription. If possible, more direct means (e.g., floppy disk) to store, retrieve, and input data to an off-line computer system will be incorporated to meet our overall project objectives to provide both immediate training data and cumulative trend data to aircrews in an expeditious manner.

Requirements for the design of an automated ACMR retrieval system include the following:

- Measurement framework specification
- Hardware acquisition (disk)
- Software design and programming
- User documentation
- Output interface (floppy disk)
- Input interface (off-line computer)*

Training Analysis for Debrief: Mission Phases and Tasks

A more detailed framework for analyzing aircrew task requirements is necessary to develop an ACMR debrief system. Aircrew tasks were broken into discrete components and allocated across the following mission phases:

- Radar search
- Radar contact and/or lock-on
- Visual search
- Initial visual acquisition (tally ho)
- Maneuver to envelope
- Weapon release
- Reattack
- Bugout

*HP 45-T is presently available for off-line analysis and debrief data format development.

Definitions provided in Table 2, previously presented, served as source material for analysis of aircrew tasks and their appropriate allocation across mission phases and aircrew members. Table 4 presents the resulting analysis of in-flight training objectives and task elements in an ACM mission framework.

Candidate Measures and Data Collection Forms

Candidate measures for selected ACMR phases and aircrew tasks are briefly summarized in Table 5. These measures correspond to more detailed descriptions presented in our preliminary debrief data collection form. A sample data collection form, together with aircrew instructions, is presented in Appendix A. To aid in the interpretation of air combat language, a glossary of terms is provided in Appendix D. The glossary also has definitions for the candidate measures selected.

The format for collecting debrief data is still under development. Future project plans call for: 1) adding other training objectives and measures, 2) deriving empirical weighting scores based on the relationship of each candidate measure to ACM success, and 3) automating ACMR data collection and analysis (both on-line and off-line).

Preliminary Debrief Data Formats

Data formats have been developed for the following ACMR training objectives:

- Radar Procedures
- Look-out Procedures
- Tactics and Maneuvers
- Envelope Recognition

These preliminary formats are designed to provide statistically summarized performance data for both immediate training feedback (on-line to ACMR) and cumulative trend analysis (off-line computer based system). Provisions have been made to include frequency measures, such as percent successful missile shots, and continuously recorded data such as range and angle-off-tail measures.

TABLE 4. ANALYSIS OF IN-FLIGHT TRAINING OBJECTIVES AND TASK DIMENSIONS (Page 1 of 6)

TRAINING OBJECTIVE/TASK DIMENSIONS	Radar Search	Radar Contact-Lock	Visual Search	Tallyho	Maneuver to Envelope	Weapon Release	Re-attack	Bugout	RESPONSIBLE AIRCREW MEMBER(s) / REMARKS
1. **Plan of Attack**									
• Analyze aircraft, weapon and opponent you'll be fighting.				═	═	═	═	═	Section/Flight Leader
• Analyze threat area in which engagement will occur.	═			═					Section/Flight Leader
• Determine formation for entering engagement.	═			═					Section/Flight Leader
• Determine minimum fuel for Bugout.								═	Section/Flight Leader
2. **Radar Procedures**									
• Designate search-lock responsibilities for section.	═								Section
• Determine eyeball and shooter responsibilities.	═			═					Section
• Determine adversary formation and position.	═			═					RIO (1) / RIO (2)
• Set-up for initial pass using offensive split.	═	═	═	═	═				Section

═ Task distribution over mission phases.

TABLE 4. ANALYSIS OF IN-FLIGHT TRAINING OBJECTIVES AND TASK DIMENSIONS (Page 2 of 6)

TRAINING OBJECTIVE/TASK DIMENSIONS	Radar Search	Radar Contact-Lock	Visual Search	Tallyho	Maneuver to Envelope	Weapon Release	Reattack	Bugout	RESPONSIBLE AIRCREW MEMBER(s) / REMARKS
3. Look Out Procedures									
• Use vertical scan technique by section.			▬	▬					Section
• Keep sight of each other.	▬	▬	▬	▬	▬	▬	▬	▬	Section
• Identify and keep sight of adversary.				▬	▬	▬	▬	▬	Section
• Determine direction of adversary and friendly movement.				▬	▬	▬	▬	▬	Section
• Make belly checks when required.					▬	▬	▬	▬	Section.
4. Provide Mutual Support									
• Keep sight of each other.	▬	▬	▬	▬	▬	▬	▬	▬	Section
• Maintain combat split.	▬	▬	▬	▬					Pilot (1) / Pilot (2)
• Communicate intentions.	▬	▬	▬	▬	▬	▬	▬	▬	Section
• Monitor maneuvering positions of section and bogey(s).					▬	▬	▬	▬	Section
• Protect each other's vulnerable areas (i.e. check wingmans six o'clock).				▬	▬	▬	▬	▬	Section

TABLE 4. ANALYSIS OF IN-FLIGHT TRAINING OBJECTIVES AND TASK DIMENSIONS (Page 3 of 6)

TRAINING OBJECTIVE/TASK DIMENSIONS	Radar Search	Radar Contact-Lock	Visual Search	Tallyho	Maneuver to Envelope	Weapon Release	Reattack	Bugout	RESPONSIBLE AIRCREW MEMBER(s) / REMARKS
5. **Section Tactics**									
• Designate free fighter.				▬	▬	▬	▬		Section
• Designate engaged fighter.				▬	▬	▬	▬		Section
• Position engaged fighter to exert pressure on adversary and kill if possible.				▬	▬	▬	▬		Engaged Fighter
• Be agressive--make adversary fly a predictable flight path.				▬	▬	▬	▬		Engaged Fighter
• Position free fighter for kill.				▬	▬	▬	▬		Free Fighter
• Maintain free fighter and engaged fighter responsibilities.				▬	▬	▬	▬		Free Fighter/Engaged Fighter
6. **Tactics and Maneuvers**									
• Predict adversary flight path.				▬	▬	▬	▬		Section
• Maneuver fighter to adversary lethal zone.				▬	▬	▬	▬		Engaged Fighter/Free Fighter
• Warp envelope away from attacking adversary.				▬	▬	▬	▬		Engaged Fighter/Free Fighter

TABLE 4. ANALYSIS OF IN-FLIGHT TRAINING OBJECTIVES AND TASK DIMENSIONS (Page 4 of 6)

TRAINING OBJECTIVE/TASK DIMENSIONS	Radar Search	Radar Contact-Lock	Visual Search	Tallyho	Maneuver to Envelope	Weapon Release	Reattack	Bugout	RESPONSIBLE AIRCREW MEMBER(s) / REMARKS
7. Energy Maintainance									
• Enter fight with good energy package.	———	———	———	———					Section
• Unload when possible to maintain energy package.				———	———	———	———	———	Section
• Make square corners--don't arc.				———	———	———	———	———	Section
• Use lag pursuit when possible.				———	———	———	———		Section
• Monitor fuel use.	———	———	———	———	———	———	———	———	Section
8. UHF Use									
• Call "Six Clear."	———	———	———	———	———	———	———	———	Section
• Give clear and concise calls.	———	———	———	———	———	———	———	———	Section
• Allow time for return flow between transmissions.	———	———	———	———	———	———	———	———	Section
• Make position calls relevant to situation.	———	———	———	———	———	———	———	———	Section
• Call all tallies, visuals and lost sight.	———	———	———	———	———	———	———	———	Section
• Transmit intentions.	———	———	———	———	———	———	———	———	Section

TABLE 4. ANALYSIS OF IN-FLIGHT TRAINING OBJECTIVES AND TASK DIMENSIONS (Page 5 of 6)

TRAINING OBJECTIVE/TASK DIMENSIONS	Radar Search	Radar Contact-Lock	Visual Search	Tallyho	Maneuver to Envelope	Weapon Release	Reattack	Bugout	RESPONSIBLE AIRCREW MEMBER(s) / REMARKS
8. UHF Use (Cont'd)									
• Make discretionary calls to wingman for Quick Kill maneuvering.				———	———	———	———		Section
• Call all bogey switches.				———	———	———	———	———	Section
9. Cockpit Coordination									
• Divide responsibilities for look out by search sector or clock position.	———	———	———	———	———	———	———	———	Aircrew (1)/Aircrew (2)
• Assign responsibility for monitoring adversary(s) position.				———	———	———	———	———	Aircrew (1)/Aircrew (2)
• Relay adversary position information to pilot/wingman as required.			———	———	———	———	———	———	Aircrew (1)/Aircrew (2)
• Analyze adversary threat position and give directive commentary to pilot.				———	———	———	———	———	Aircrew (1)/Aircrew (2)
10. Weapon Selection and Switchology									
• Select weapon appropriate to tactical situation.	———	———	———	———	———	———	———		Aircrew (1)/Aircrew (2)
• Set correct switches in cockpit to fire weapon of choice.	———	———	———	———	———	———	———		Aircrew (1)/Aircrew (2)

TABLE 4. ANALYSIS OF IN-FLIGHT TRAINING OBJECTIVES AND TASK DIMENSIONS (Page 6 of 6)

TRAINING OBJECTIVE/TASK DIMENSIONS	Radar Search	Radar Contact-Lock	Visual Search	Tallyho	Maneuver to Envelope	Weapon Release	Reattack	Bugout	RESPONSIBLE AIRCREW MEMBER(s) / REMARKS
10. **Weapon Selection and Switchology** (Cont'd									
• Project and fly aircraft to a point within envelope for weapon of choice.				———	———	———	———		Aircrew (1)/Aircrew (2)
11. **Envelope Recognition**									
• Estimate/recognize range and closing velocity.					———	———			Aircrew (1)/Aircrew (2)
• Estimate/recognize angles off and pointing requirement.					———	———			Aircrew (1)/Aircrew (2)
• Analyze other relevant factors, e.g. sun angle, wingman position, clutter, etc.					———	———			Aircrew (1)/Aircrew (2)
12. **Bugout Procedures**									
• Determine requirement and capability for reattack.							———	———	Aircrew (1)/Aircrew (2)
• Predict disengagement time on fuel and battle situation.	———	———	———	———	———	———	———	———	Section
• Bugout while protecting section lethal zones.								———	Section

TABLE 5. CANDIDATE MEASURES *

MISSION PHASE**	CANDIDATE MEASURES
Radar Search and Acquisition	• Radar Opportunity (yes, no) • Radar Contact (yes, no) • Radar Lock (yes, no) • Range and Time of Contact • Range and Time of Lock-On
Visual Search and Acquisition	• Tally Ho (yes, no) • Range and Time of Tally Ho
Maneuver to Envelope	• Time and Frequency in Offensive, Neutral, or Defensive State • Fighter First Shot Opportunity (yes, no) • Fighter First Kill (yes, no) • Elapsed Time to First Shot, First Kill
Envelope Recognition	• Interaircraft Range • Angle-Off-Tail (AOT) • Closing Velocity (Vc) • Indicated Airspeed (IAS) • Antenna Train Angle (ATA)*** • Missile Simulation Result (kill or no-kill)

*See glossary for definitions.

** Search and Acquisition phases for radar and visual portion of engagement have been combined to simplify this presentation.

*** Aircraft pointing

Examples of these data formats and their measurement applications are presented below for each of the above listed training objectives.

Radar Procedures. Tactical doctrine specifies a requirement to quickly locate an adversary through effective use of onboard radar equipment. An early radar contact provides aircrews with essential position data required to facilitate visual acquisition of an adversary. Also, radar contact and lock-on are required to launch certain air-to-air missiles. Figure 5 illustrates two candidate measures for assessing radar performance based on success rate and ACMR tracking data. Both of these measures have demonstrated sensitivity in discriminating radar performance differences between some operational units. Performance comparisons presented in Appendix B illustrate the unit statistical comparisons.

Look-out Procedures. One of the important elements of "Look-out Doctrine" specifies obtaining an initial visual acquisition (tally ho) as early in the ACM engagement as possible. Obtaining an early tally ho and keeping sight of an adversary is required for both offensive (maneuvering to opponents lethal zone) and defensive (protecting your own lethal zone) air combat. Figure 6 presents sample data formats related to successful visual search and acquisition procedures. Statistical performance comparisons of visual acquisition between squadron units are also presented in Appendix B.

Tactics and Maneuvers. In order to get within an adversary lethal zone, a pilot must first maneuver his aircraft to arrive at the proper weapon fire position. Needless to say, an opponent in air combat has the same goal. The results of this maneuvering between ACM opponents can be analyzed in terms of offensive (+), defensive (-), and neutral (o) engagement states defined in terms of wingline geometry and proximity to an opponents lethal zone.[10]

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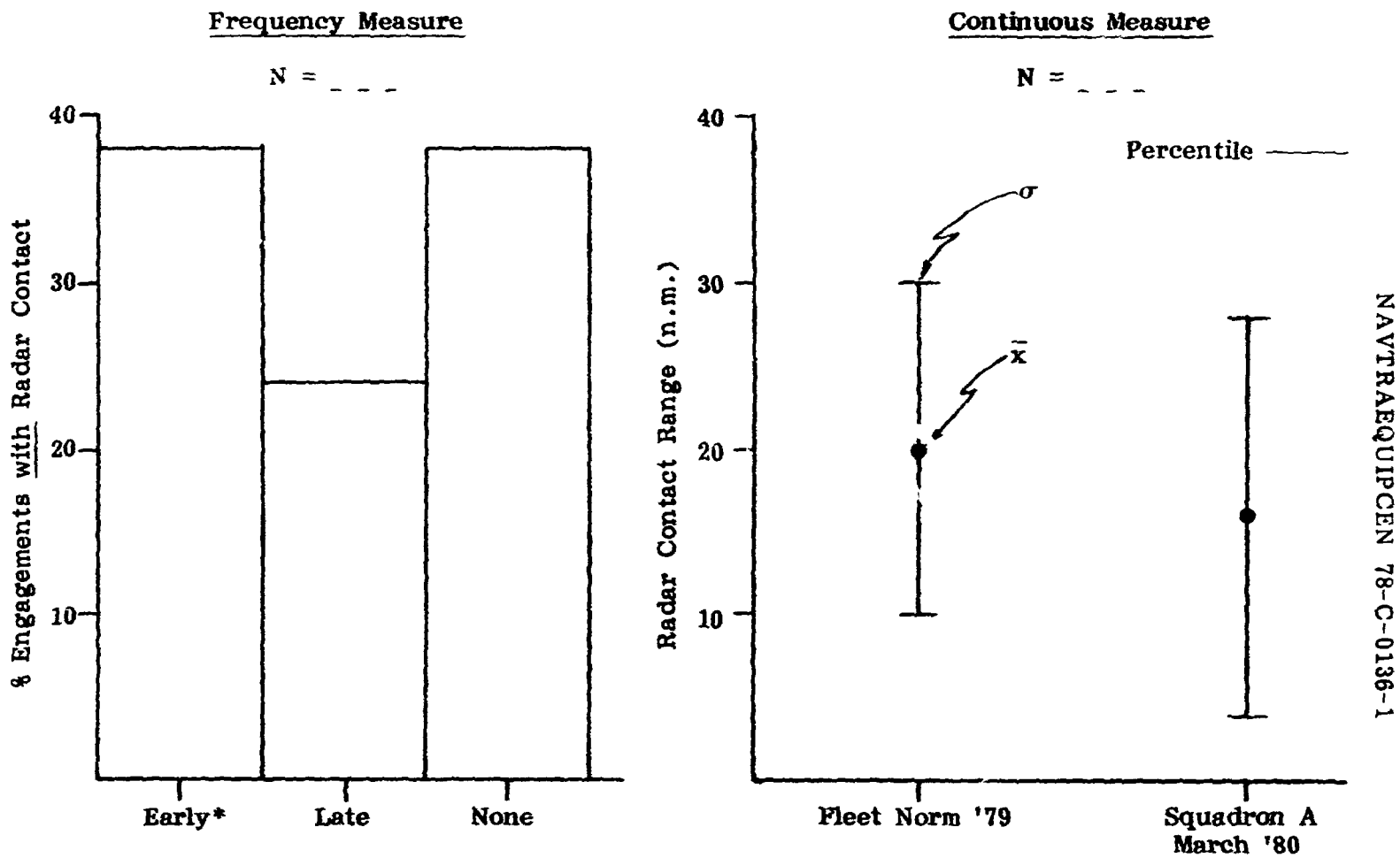
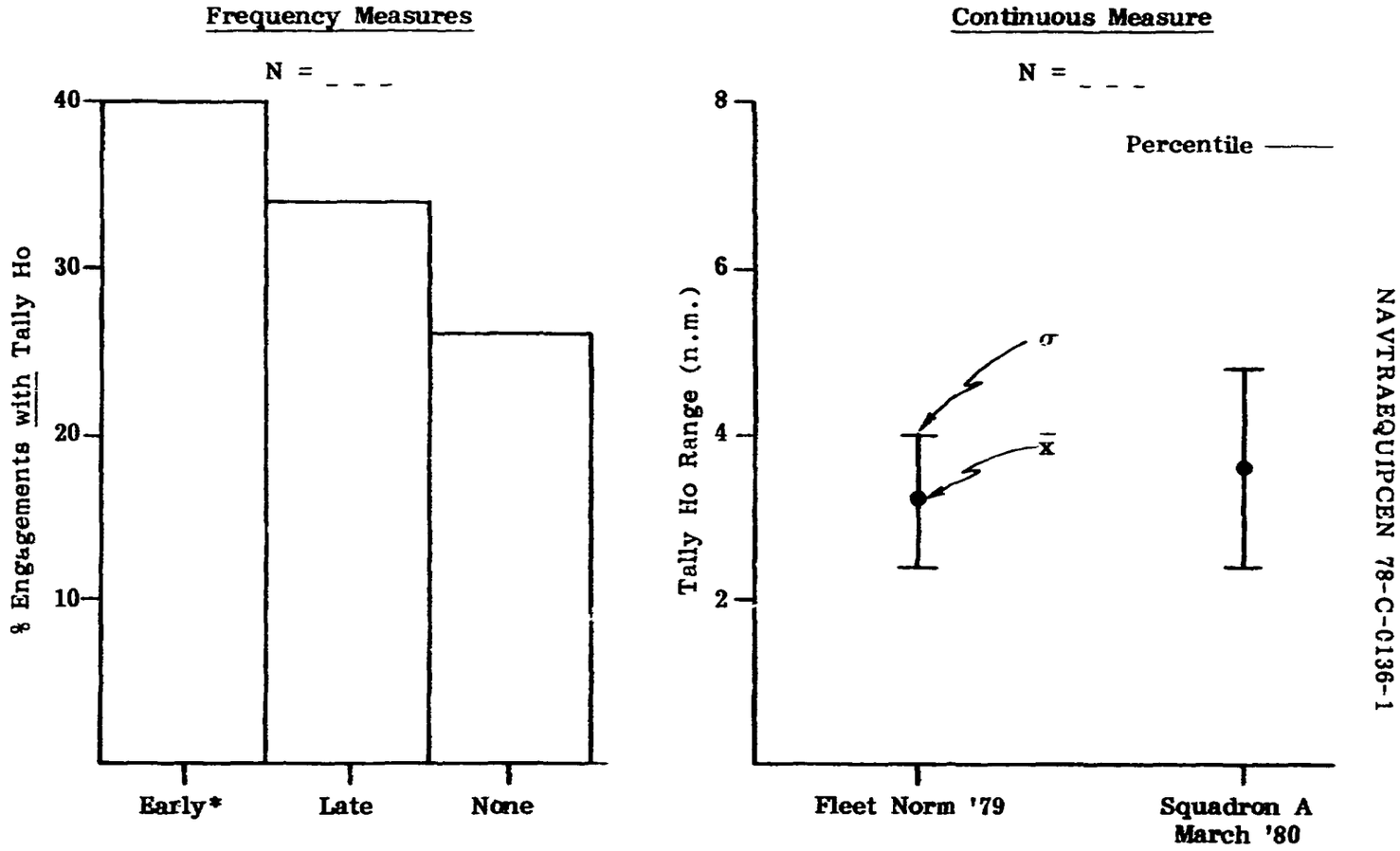
[10]See footnote 8, page 24.



*Specified by tactical doctrine.

Figure 5. Radar Contact Data Format Samples: Illustrates frequency measures (percent engagements with early, late, and no radar contact) and continuous measures [mean ($\bar{x}$) and standard deviation (σ)] radar contact range



*Specified by tactical doctrine.

Figure 6. Tally Ho Data Format Samples: Illustrates frequency measures (percent engagements with early, late, and no Tally Ho), and continuous measures [mean ($\bar{x}$) and standard deviation (σ)] Tally Ho range

A well developed ACMR performance measurement index (PMI) is currently available for incorporation into the proposed debrief system.[11] Figure 7 presents data formats related to tactics and maneuvers. Candidate measures include percent fighter first shots, percent fighter first kills, and continuous time-based measures using the PMI. In addition, elapsed time to first shot, first kill and survival time can be added to the debrief measurement framework using similar data formats.

Envelope Recognition. In order to defeat an opponent during an air combat engagement a pilot must fire his weapon within the boundaries of a launch envelope. As a rule, weapon launch boundaries are specified in terms of inter-aircraft geometry, such as range and angular limits. Success rates and weapon launch accuracy can be determined in terms of inter-aircraft position data available on ACMR. Figure 8 presents sample data formats for selected measures of envelope recognition performance. Success rates can be computed from ACMR simulation outcomes (kill, no-kill) or from doctrine envelope boundary limits. For example, Figure 9 presents an array of rear-hemisphere missile fire points in a polar plot format. Each of these fire points may be scored by ACMR or through application of doctrine launch envelopes which depict range and angular limits. More information regarding precise boundaries of weapon fire limits will be presented in a later volume of this Interim Report (Volume II). Unit comparisons for envelope recognition performance are presented in Appendix B.

Other Training Objectives. Measurement scales for the remaining training objectives (Table 4) are not presently available. In fact, some training objectives such as "mutual support" and "cockpit coordination" may be impossible to quantify objectively through use of ACMR outputs. The requirement to include such "unmeasurable" training objectives in our final debrief design will be

[11] Simpson, W.R., Oberle, R.A. The Numerical Analysis of Air Combat Engagements Dominated by Maneuvering Performance. Patuxent, MD: Naval Air Test Center, June 1977.

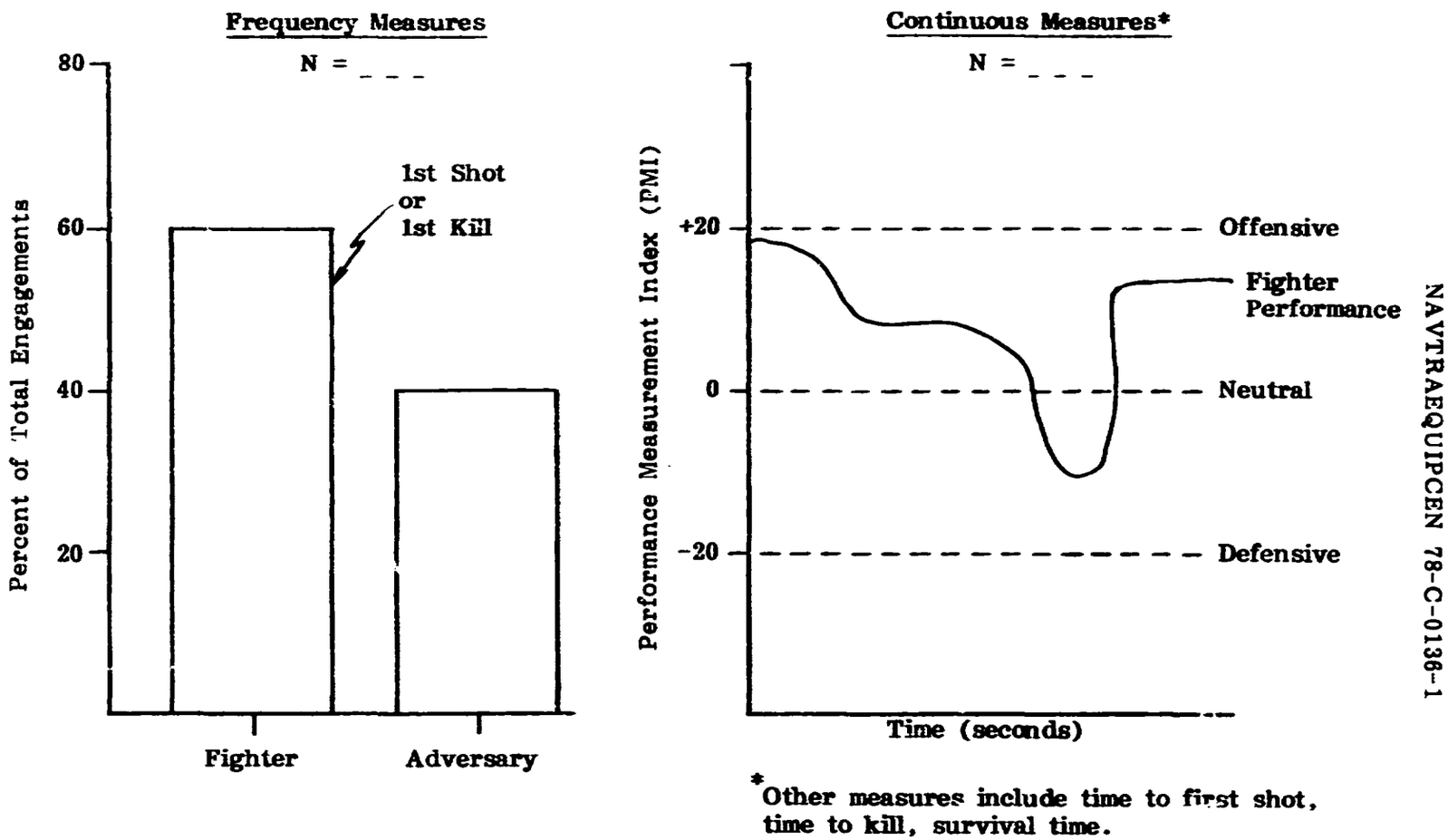


Figure 7. Tactics and Maneuvers Data Format Samples: Illustrates frequency measures (percent first shots and first kills across engagements) and continuous measures (PMI score over time)

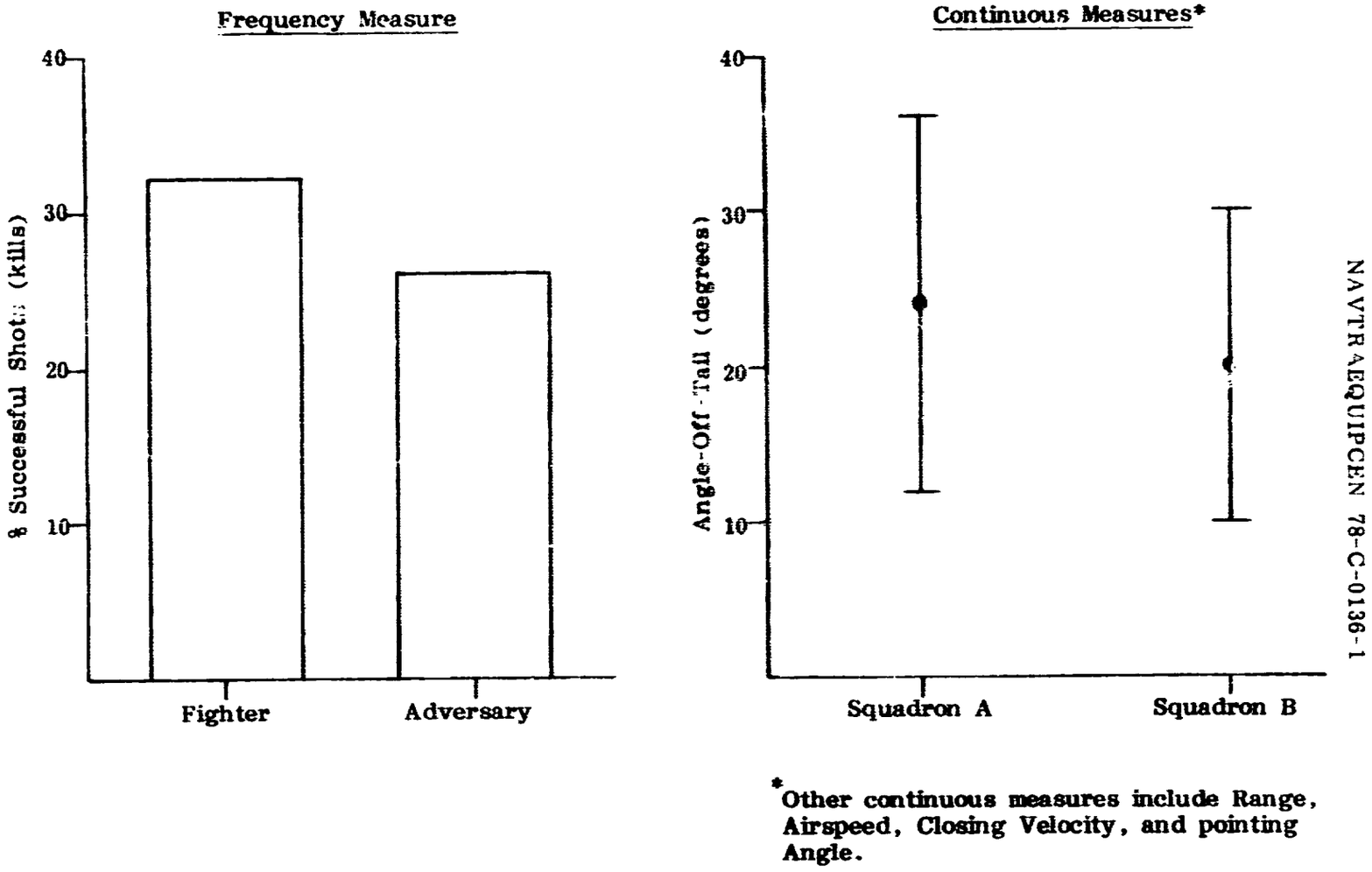


Figure 8. Envelope Recognition Data Format Samples: Illustrates frequency measures (percent successful missile shots) and continuous measures [mean ($\bar{x}$) and standard deviation (σ)] for angle-off-tail

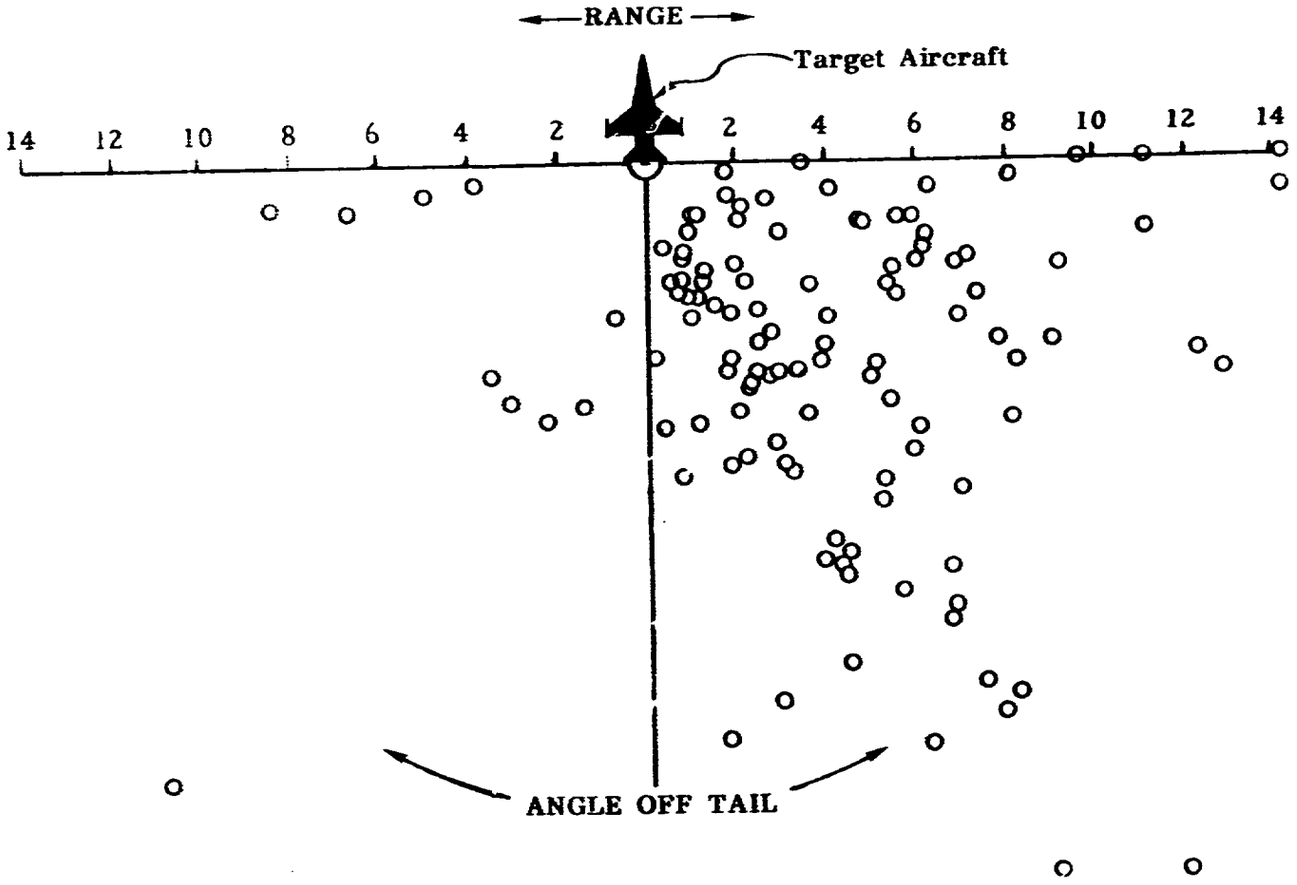


Figure 9. Envelope Recognition Data Format Sample: Depicts fighter aircraft position at time of missile fire. Fire points (circles) are plotted as function of range (0-14 Kft) and angle-off-tail (degrees) from the target aircraft

explored during later phases of debrief development. An adequate sampling of debrief content may call for inclusion of subjective measurement methods for estimating performance effectiveness on those ACM tasks which are not amenable to objective measurement approaches.

On the other hand, the training objective, "energy maintenance" can be objectively quantified. Candidate measures related to energy management may be available through use of the energy maneuverability display (EMD) which is currently under development. A sample ACMR display format for the EMD is provided in Appendix C.

Requirements for a Computer Based System

The previous report section has reviewed some of the data formats on selected ACM training objectives and their associated tasks. Performance measures for search and locate tasks (radar and tally ho), tactics and maneuvers, and envelope recognition are currently available. Later additions for measuring other ACM task performance also are planned. The capability of comparing these measures with those which have been previously documented, i.e., longitudinal analysis, will permit evaluation of statistical trends relative to established fleet norms.

During the course of the program to develop ACMR debrief methods, it has become increasingly obvious that a computer based system will be required to more rapidly process and display performance based debrief information. For Navy aircrews undergoing training, this means that performance data for critical ACM tasks must be available on a timely basis, and must appear in a format understandable by aircrews under instruction.

Information required during debrief, and in later training reviews, will range from simple bar charts comparing performance on single engagements to more complex presentations such as fighter position at weapon fire in several dimensions and perspectives

In addition, it is important that squadron training officers have available a rapid retrieval filing system of "normative" data in order to evaluate progress in training over time.

The requirements of a computer based system are twofold.

1) The computer provides a system off-line from ACMR which will serve as a vehicle for developing and testing appropriate ACMR debrief data formats (for later incorporation to ACMR).
2) The computer serves as a prototype off-line system for storage, processing, and display of ACMR training data required for trend analysis (longitudinal review of training progress) and normative data bank development.

Computer Selection and Acquisition

Selection Criteria. It is essential that several global requirements for selection of a candidate system be met. These particular requirements are itemized and discussed below:

1) System Access and Transportability
2) Store Data in Retrievable Files
3) Direct Edit of Files
4) Cross Tabs and Matrix Manipulation
5) Statistical Analysis of Data
6) Interactive Graphics Capability (CRT Display)
7) Hardcopy Print-out
8) Secure Data Files

System Access and Transportability. The candidate system will be used initially to develop and test various performance data formats required for training debrief design. Since it is expected that the process of developing and testing debrief methods will involve interaction with on-site operational aircrews, regular daily access to the computer based system will be a requirement. Transportability is a much desired design feature for this purpose.

Data Files. Reviews of ACMR training data frequently entail comparisons between current performance trend data with previously documented

results. Comparisons of this type are essential to estimate training progress over time for both individual aircrew members and their squadron units. In addition, stored information related to various combinations of aircrews, aircraft types, weapon systems, mission profiles and operating conditions must be available to a user on request in order to make appropriate performance trend comparisons. For these reasons storage and retrieval of potentially large data files is considered a mandatory system requirement.

Direct Edit. Incoming ACMR data, collected under field conditions, must be carefully edited to establish an uncontaminated data base. Direct editing of files assures expeditious manipulation of incoming data for file construction and for retrieving data subsets required for diagnostic training feedback of performance on selected aircrew tasks. Edit routines should include capability for cross tabs and matrix manipulation in order to permit access to required data subsets.

Statistical Analysis. The foundation of the developing ACMR debrief system rests on comprehensive statistical analysis and review of ACMR data. A candidate computer system ideally would have a menu selection of both descriptive and inferential statistical programs for summarizing and testing performance trends.

Interactive Graphics Capability. The application of state-of-the-art computer graphics is a user oriented requirement. Initially, interactive graphics will permit experimentation and selection of graphic presentation methods which have high operational utility. Data displays depicting performance on selected aircrew tasks in a readily understandable format will be incorporated in the final debrief system design.

Hardcopy print-out will provide the capability for recording results for later review and analysis for individual aircrew members following a debrief, and in addition, will serve to document results for fleet training files and longitudinal analysis.

Secure Data Files. In view of the sensitive nature of recording performance capabilities of Naval aircrews and the potential of classified content, it will be necessary to have secure ACMR data files.

Requirements Summary. Development of a practical system for ACMR debrief will require a computer based system in order to store, process, retreive, and display rapidly, performance trend data essential for timely training feedback. Although preliminary methods have been developed and tested on selected air combat tasks, further refinement and implementation of a debrief system will best be served through automation methods. To meet this need for automation it is recommended that a mini-computer system be used. At a minimum, such a system should be readily accessible, preferably portable, capable of editing, storing, and retrieving sizeable files, and feature both a statistical library and interactive graphics (CRT). An additional requirement for secure data files is recommended.

Computer Acquisition. Candidate computer systems were reviewed[12] and evaluated with respect to the above selection criteria. On the basis of this evaluation, the Hewlett-Packard (HP) 45-T system was selected. The HP 45-T System is a state-of-the-art desktop computer which provides rapid file storage and retrieval, editing and matrix manipulation, ready software for statistical analysis, interactive graphics, and comes complete with CRT display and built-in hardcopy output. A strong point in favor of the HP 45-T is its compact design, with the clear advantage of transportability. The HP 45-T has subsequently been delivered (December 23, 1979) and is currently undergoing system checkout, and software inventory. Application of the HP 45-T system to computer based debrief design is discussed in the next section of this report. Table 6 lists the major hardware and software features of the HP 45-T computer.

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[12]Dunlap and Associates, Inc. Requirement for a Computer Based ACMR Debrief System. Technical Memorandum 234-4, July 29, 1979.

TABLE 6. SUMMARY DESCRIPTION OF HP 45-T MINI COMPUTER

Major Hardware Features

- 187 K byte main memory
- 12" CRT display (80 character, 24 lines)
- Two cassette tape drives (217 K bytes)
- Keyboard alpha numeric input
- Internal thermal printer
- Interactive graphics ROM
- Special function keys

Software Presently Available

- Graphics ROM
- General Statistics
- Regression analysis (linear)
- Regression analysis (non-linear)
- Analysis of variance
- Statistical graphics
- Supplementary utility programs (mass storage and file manipulation)

System Expansion Potential

- 480 K byte main memory
- Mass storage ROM
- Flexible or hard disk drive
- High speed printer
- Card reader
- A-D converter (digitizer)

SECTION IV

FUTURE REQUIREMENTS

Criterion Measurement Research

We have defined a "criterion measure"[13] as an acceptable standard by which a decision or judgment may be made. This definition presumes that the candidate measures selected and their associated performance tolerances have satisfied both statistical and operational requirements specified in an earlier section of this report (e.g., validity, operational acceptance). Figure 10 summarizes the relationship between ongoing criterion development (measurement research) and debrief development (measurement application). Candidate measures themselves must meet high standards of excellence. For this reason, the quality of the criterion research has been, and will continue to be the foundation for an effective debrief system. The final debrief design will rest on statistically and operationally verified measures; with emphasis on both overall ACM performance assessment and diagnostic appraisal in specific task areas.

Performance Assessment and Appraisal System (PAAS)

Overview. We have chosen to name the ACMR debrief system the "Performance Assessment and Appraisal System (PAAS)" in order to emphasize its application to overall ACM performance assessment and diagnostic appraisal. As indicated previously, PAAS will be a computer based system which uses an HP 45-T. The HP computer provides extensive statistical software packages which will have direct application for debrief design (see Table 6).

In addition, it will be necessary to develop special purpose software programs for the debrief system to complement the HP 45-T off-the-shelf software. The special purpose programs will serve primarily to: 1) select and integrate off-the-shelf statistical routines for ACM performance review, 2) include user

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[13] See footnote 1, page 7

Requirements Met

- ACM Operational Analysis
- Integrated Sets of Performance Data
- Performance Criteria and Assessment Methods
- Content Validity for Measures of ACM

Future Requirements

- Validity and Reliability Tests for Measures of ACM
- Inclusion of New Aircraft, Weapons, and Tactics (data collection and analysis)
- Performance Criteria and Assessment Methods for Other Training Objectives
- Automated Data Extraction (on-line)

Requirements Met

- ACM Training Objectives and Aircrew Tasks
- Preliminary Debrief Checklist and Data Formats
- Performance Based Debrief Analysis
- Training Feedback and Diagnostic Data

Future Requirements

- Relative Contribution (weighting coefficients) of Measures to ACM Success
- Debrief Content Revisions and Methods Update
- Expansion of Performance Based Debrief
- Automated Data Processing and Display (off-line)

Figure 10. Relationship Between Criterion Development and Training Improvement Projects

oriented instructions for computer operation and performance evaluation, and 3) develop a coherent, sequential analysis package for performance assessment and diagnostic appraisal, including such factors as data taxonomy, file construction, editing and file manipulation, and menu selection of various programs and statistical analysis methods.

Software Development. The PAAS will be comprised of four principal programs: Standard Operating Procedures (SOP), Performance Assessment and Combat Effectiveness (PACE), Numerical Operational Readiness Measurement (NORM), and Training Appraisal and Diagnostics (TAD).

Standard Operating Procedures (SOP). The SOP will be a user oriented program which provides an introduction to PAAS, complete operating procedures, program listing and description, and a menu selection of other available programs. Design features of SOP will include the use of branching programming methods to facilitate application by operational users with varying levels of operating skill and system familiarity.

Performance Assessment and Combat Effectiveness (PACE). The PACE program will be designed to provide a menu selection of ACM performance analysis and assessment methods subroutines. This program is used for air combat effectiveness across various training objectives. Provisions are made in the PACE program for file construction and manipulation, including a data taxonomy categorization by unit, aircraft type, weapons, aircrew and mission variables. Analysis subroutines can be used primarily to evaluate performance for a single ACM detachment or training period, at the airwing, squadron unit, and aircrew level of analysis. Various doctrine referenced criteria (e.g., missile envelope thumbrules) may be selected and applied for conducting performance assessment against fleet training standards.

Numerical Operational Readiness Measurement (NORM). The NORM software package will permit cumulative storage of performance data files, unit and aircrew training records, edit and file update routines, and rapid storage and retrieval of fleet, unit, and individual aircrew data. A menu selection of summary statistics and analysis routines will be available for

longitudinal analysis (using a normative data base) of training progress against norm referenced performance criteria.

Training Appraisal and Diagnostics (TAD). The TAD program will provide a capability for detailed analysis of a selected training objective and its associated aircrew task performance. Summarization of aircrew strengths and weaknesses, together with recommended remedial training will be provided.

Software Integration. Figure 11 presents the organization of PAAS in terms of its principal software programs. An important design feature of PAAS will be the integration of these individual programs into a coherent, user oriented system. Design plans call for an interactive system having program branches which allow ready access and cross-communication between the various PAAS programs and subroutines. With this approach, a user should be able to review his own performance and compare it to fleet standards (PACE), while also having the capability to call normative data (NORM) for performance comparisons to fleet levels. In addition, TAD will give training officers the capability to review and correct training deficiencies.

Future Project Plans

Immediate project plans call for computer programming, software development and integration of the previously described PAAS software packages. System operation, proposed programs, and data formats will be tested in interactive sessions with operational aircrews. A demonstration system will be designed and ready for review in approximately six months. Long-range project plans include further research efforts to develop candidate measures for other air combat tasks, e.g., energy maneuverability and to incorporate new data formats from selected measures into the debrief system. Consideration will be given to meeting high performance measurement standards (validity, reliability, and operational utility), and for reviewing other ongoing training applications of performance based training aids.[14]

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[14] Mitchell, D.R. Trainee monitoring, performance measuring, briefing, and debriefing. In 1st Interservice Industry Training Equipment Conference (NAVTRAEQUIPCEN IH-316). Orlando, Florida: Naval Training Equipment Center, November 1979.

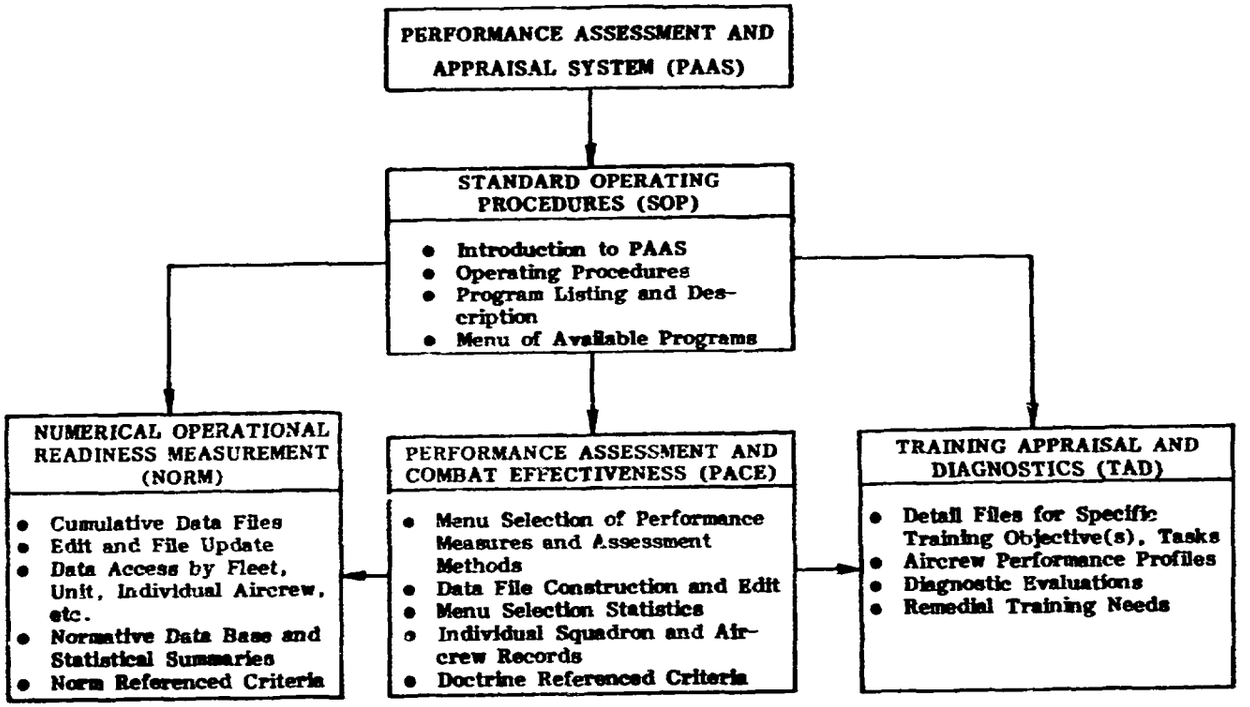


Figure 11. Organization of the Performance and Appraisal System

SECTION V

SUMMARY AND DISCUSSION

Volume I of this Interim Report has presented an overview of the technical approach to ACMR debrief development, and a preliminary debrief design based on key training objectives and their associated aircrew task measures. The requirements for a computer based debrief system were discussed, together with the rationale for selection of the HP 45-T System. Preliminary data formats for key training objectives were presented. Finally, ACMR debrief software packages which are currently under development were identified and described.

The preliminary debrief design presented in this report represents an outgrowth of an ongoing criterion development (measurement research) program. We have relied heavily on the extensive experience gained on ACMR and our knowledge of ACM and ACM measurement as a foundation for designing a debrief system that provides a well defined measurement approach. The proposed debrief system is responsive to an operational requirement for both overall performance assessment and diagnostic appraisal. For this reason we have chosen to call our debrief system the "Performance Assessment and Appraisal System (PAAS)."

Future plans have been outlined, and center chiefly on the development of a demonstration system for ACMR debrief. Further development of criterion measures across remaining training objectives will be necessary to complete a final debrief design such that it represents a full treatment of "all aspect ACM" performance evaluation. We have in the past, and propose for the future, to maintain close coordination with fleet operational personnel in order to deliver a final product which closely matches their ACMR training requirements.

APPENDIX A

PRELIMINARY AIMR DEBRIEF CHECK LIST FOR MANUAL SYSTEM

- AIRCREW INSTRUCTION SHEET
- DEBRIEF QUESTIONNAIRE FORM

AIRCREW INSTRUCTION SHEET

Live operation

1. Call radar contact by aircraft number.
2. Call initial Tally ho by aircraft number.
3. Call lost tallies and visuals.
4. Call Fox 1 and Fox 2.
5. Start ACM switch at 8 miles.

Debriefing

1. Operating status information such as:
   - Radar
   - VTAS/Seam
   - Aircraft and Subsystems
2. Debrief analysis:
   - Conduct debrief by ACM mission phase.
   - Complete debrief checklist for each fighter aircrew and/or section

ACMR PERFORMANCE ASSESSMENT AND APPRAISAL SYSTEM (PAAS)

OBJECTIVE — MISSION PHASE

Radar Procedures . . . . . Radar Search and Acquisition

Critical Tasks

- Designate search-lock responsibilities for section . . . . . Yes___No___
- Determine eyeball and shooter responsibilities . . . . . Yes___No___
- Operate radar equipment to establish an early contact . . . Yes___No___
- Determine adversary formation and position . . . . . Yes___No___
- Set-up for initial pass using offensive split and to enter fight with best tactical advantage. . . . . Yes___No___
- Overall performance for radar procedures[1] . . . . . S___OK___W___

Relative Importance . . . . . _____(weighting coefficient)[2] in computing total score.

Measurement Scales

- Radar Status . . . . . .Up____Down____ ...Time____Range____
- Radar contact . . . . . .Yes___No___A/C#___Time____Range____
- Radar lock . . . . . .Yes___No___A/C#___Time____Range____
- Early — Late

32 or more	31-26	25-21	20-16	15-11	10-6	5-1
☐	☐	☐	☐	☐	☐	☐

Miles

Instructor Comments

_____

_____

_____

_____

_____

[1]Strong (S), OK, weak (W) category rating scale used by training officers.

[2]To be determined from results of ongoing criterion measurement research.

ACMR PERFORMANCE ASSESSMENT AND APPRAISAL SYSTEM (PAAS)

OBJECTIVE — **MISSION PHASE**

Lookout Procedures . . . . . Visual Search and Acquisition[3]

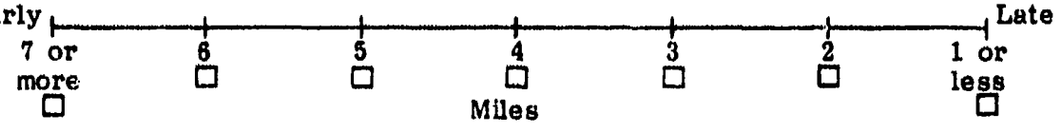
Critical Tasks

- Keep sight of each other . . . . . Yes___No___
- Identify and keep sight of adversary(s) . . . . . Yes___No___
- Re-acquire adversary after losing sight . . . . . Yes___No___
- Determine direction of adversary and friendly movement . . Yes___No___
- Make belly checks when required . . . . . Yes___No___
- Overall performance for lookout procedures . . . . . S___OK___W___

Relative Importance . . . . . _____(weighting coefficient) used in computing total score.

Measurement Scales

- Tally Ho before first pass (merge plot). . . . . Yes___No___
- Tally Ho _____aircraft in fighter section. (How many?)
- Tally Ho _____aircraft in bogey section. (How many?)
- First Tally Ho made by A/C#___on A/C#___: Time_____Range_____
- Early



Instructor Comments

_____

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[3]Search and acquisition phases have been combined to simplify analysis.

ACMR PERFORMANCE ASSESSMENT AND APPRAISAL SYSTEM (PAAS)

OBJECTIVE — MISSION PHASE

Tactics and Maneuvers . . . . . Maneuver to Envelope

Measurement Scales

- Time and Frequency in Offensive-defensive states[4] F_____A_____
- Fighter vs Adversary First Shot opportunity F_____A_____
- Fighter vs Adversary First Shot time elapsed F_____A_____
- Fighter vs Adversary First Kill obtained F_____A_____
- Fighter vs Adversary First Kill time elapsed F_____A_____
- Scoring method for Kill determination: ACMR Mode__Other__

Instructor Comments

_____

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[4]These measures will be derived from Readiness Estimation System (RES). The RES is described in footnotes 8 and 9, pages 24 and 26.

ACMR PERFORMANCE ASSESSMENT AND APPRAISAL SYSTEM (PAAS)

OBJECTIVE — MISSION PHASE

Tactics and Maneuvers . . . . . Maneuver to Envelope

Critical Tasks

1) Use recommended offensive tactics to:

- Predict adversary flight path — Yes___No___
- Make adversary predictable — Yes___No___
- Maneuver to adversary lethal zone — Yes___No___
- Obtain a quick kill (1 min.) — Yes___No___

2) Use recommended defensive tactics when required to: N/A___Yes___No___

- Warp envelope away from attacking adversary — Yes___No___
- Mask/reduce your own target signature (i.e., come to idle, stay in clutter) — Yes___No___
- Neutralize remaining threat and safely disengage — Yes___No___

Relative Importance . . . . . _____

(weighting coefficient) used in computing total score.

ACMR PERFORMANCE ASSESSMENT AND APPRAISAL SYSTEM (PAAS)

OBJECTIVE — MISSION PHASE

Envelope Recognition . . . . . Weapon Release

- Satisfy radar lock or tone as required — Yes___No___
- Meet range and angle requirements — Yes___No___
- Meet pointing requirements — Yes___No___
- Satisfy closing velocity requirements — Yes___No___
- Meet other weapon fire restrictions, i.e., clear of clutter,* and wingman — Yes___No___

Relative Importance . . . . . _____ (weighting coefficient) used in computing total score.

Measures

Missile Shots

No.	Time	Shtr/Tgt	Missile	Range	AOT	Result	Remarks
1-1							
1-2							
1-3							
1-4							
1-5							
1-6							
1-7							
1-8							

* For AIM 7 - check horizon line and look down
  For AIM 9 - check sun position and terrain (when necessary)

ACMR PERFORMANCE ASSESSMENT AND APPRAISAL SYSTEM (PAAS)

OBJECTIVE MISSION PHASE

Envelope Recognition . . . . . Weapon Release

Measures (Cont'd)

Missile Shots

No.	Time	Shtr/Tgt	Missile	Range	AOT	Result	Remarks
2-1							
2-2							
2-3							
2-4							
2-5							
2-6							
2-7							
2-8							

Extra Missile Shots

-1 _____

-2 _____

-3 _____

-4 _____

Gun Shots

No.	Time	Shtr/Tgt	Range	Track Time	Result
-1					
-2					
-3					

Instructor Comments: _____

APPENDIX B

SQUADRON PERFORMANCE COMPARISONS*

- Radar Contact and Tally Ho
- Empirical Envelopes

*Performance comparisons using doctrine envelope boundary scoring methods are presented in Volume II of this Interim Progress Report.

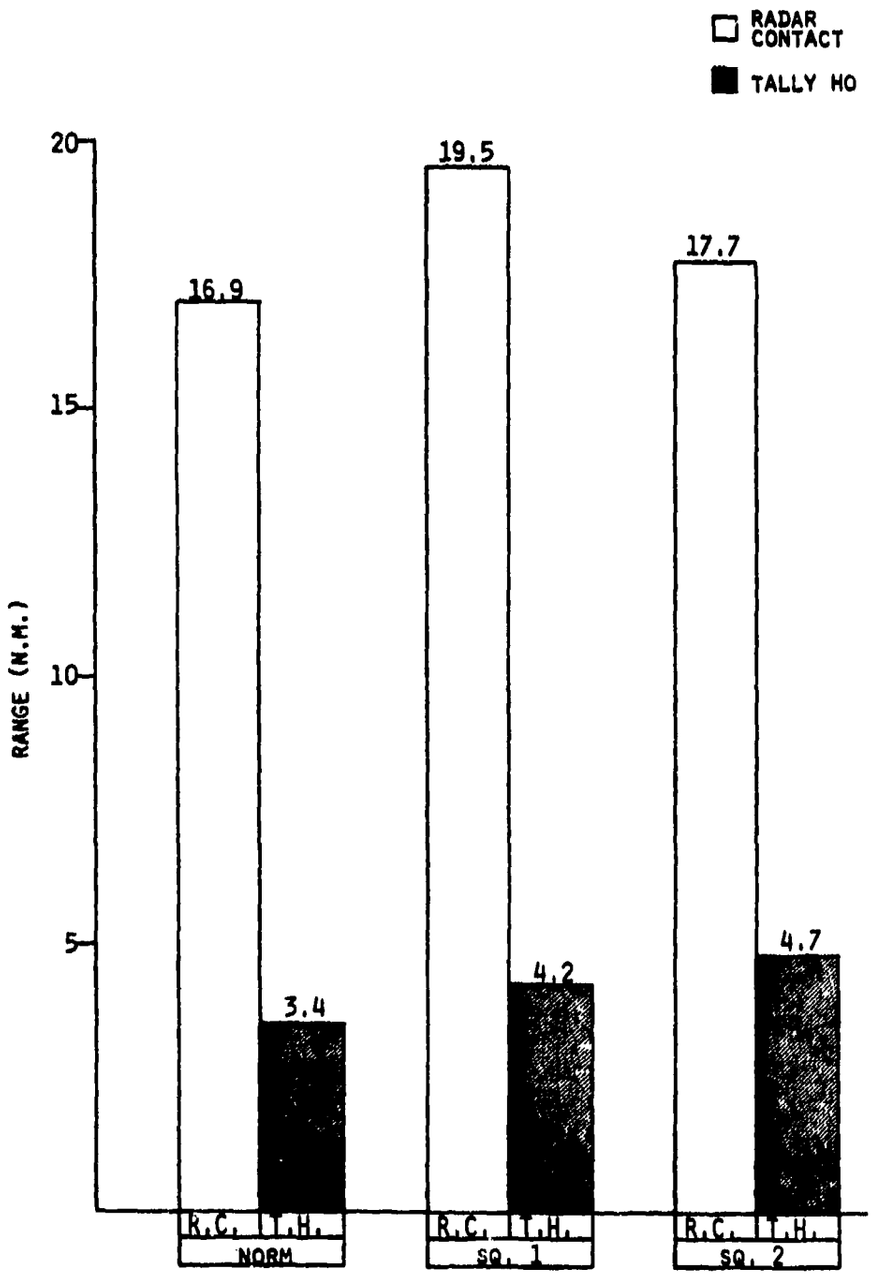

Figure B-1. Search and Locate Measures: Mean range to target for radar contact (R.C.) and Tally Ho (T.H.) comparing two F4 squadrons (SQ 1 and 2) to fleet norm.

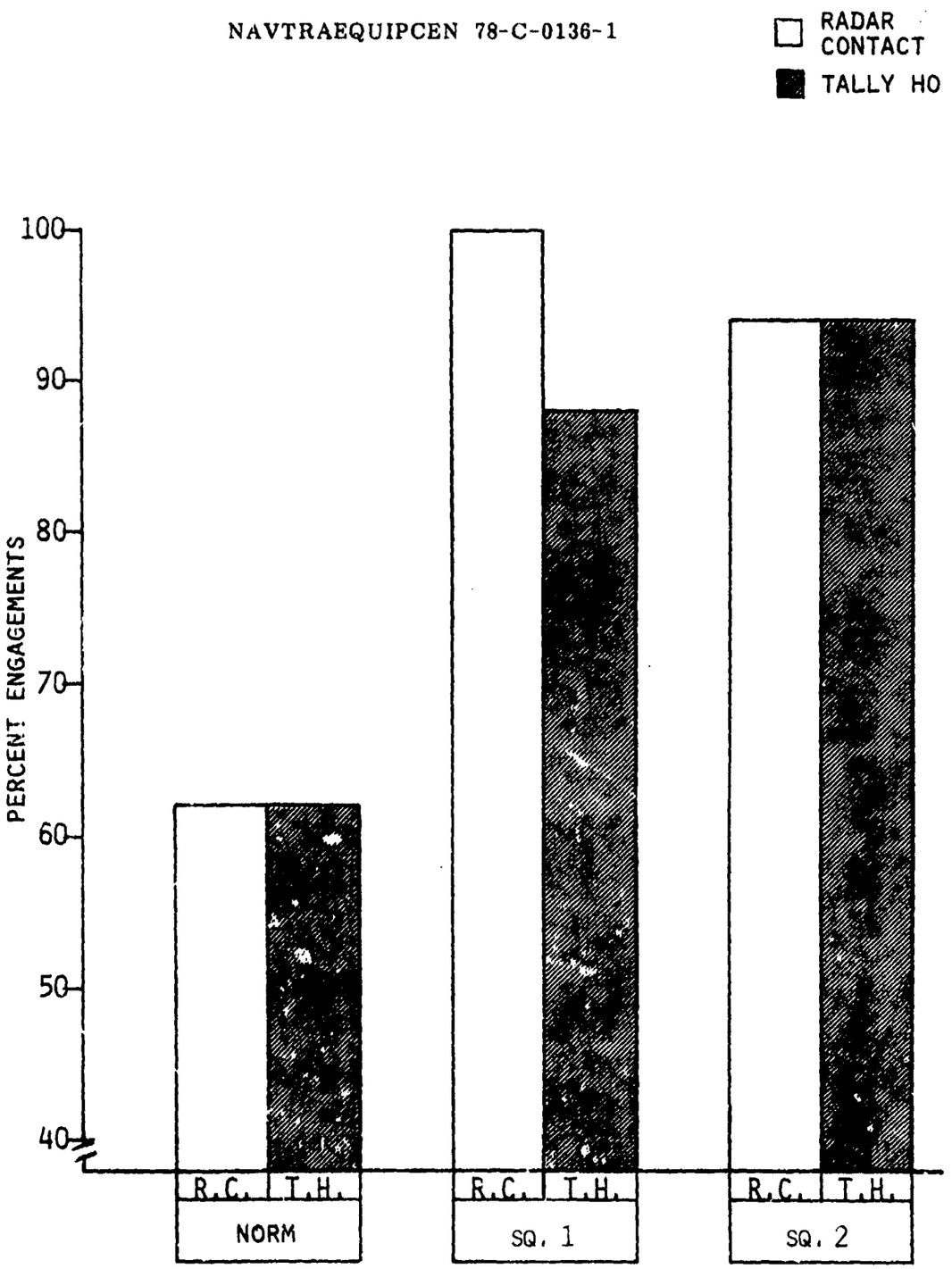

Figure B-2. Search and Locate Measures: Percent radar contacts (R.C.) and Tally Ho (T.H.) comparing two F4 squadrons (SQ 1 and 2) to fleet norm.

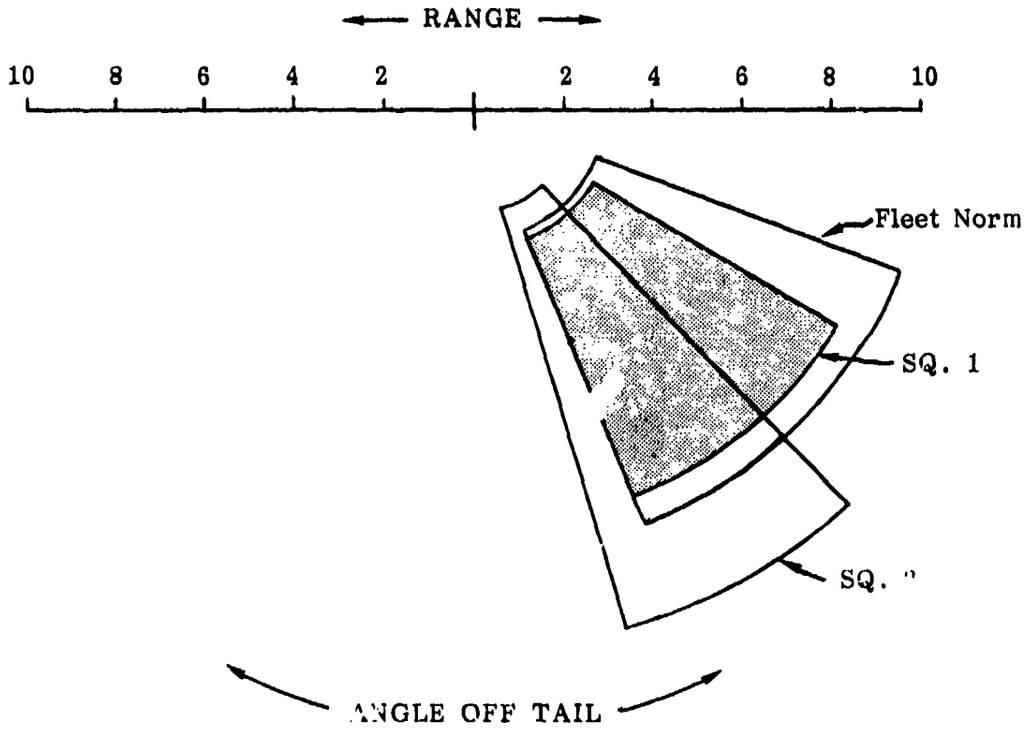

Figure B-3. Envelope Recognition Measures: Empirical envelopes ($\bar{x} \pm 1\sigma$) based on range and angle measures, comparing empirical boundaries for two F4 squadrons (SQ 1 and 2) to fleet norm

APPENDIX C

EMD SAMPLE

DATA FORMAT FROM ACMR[5]

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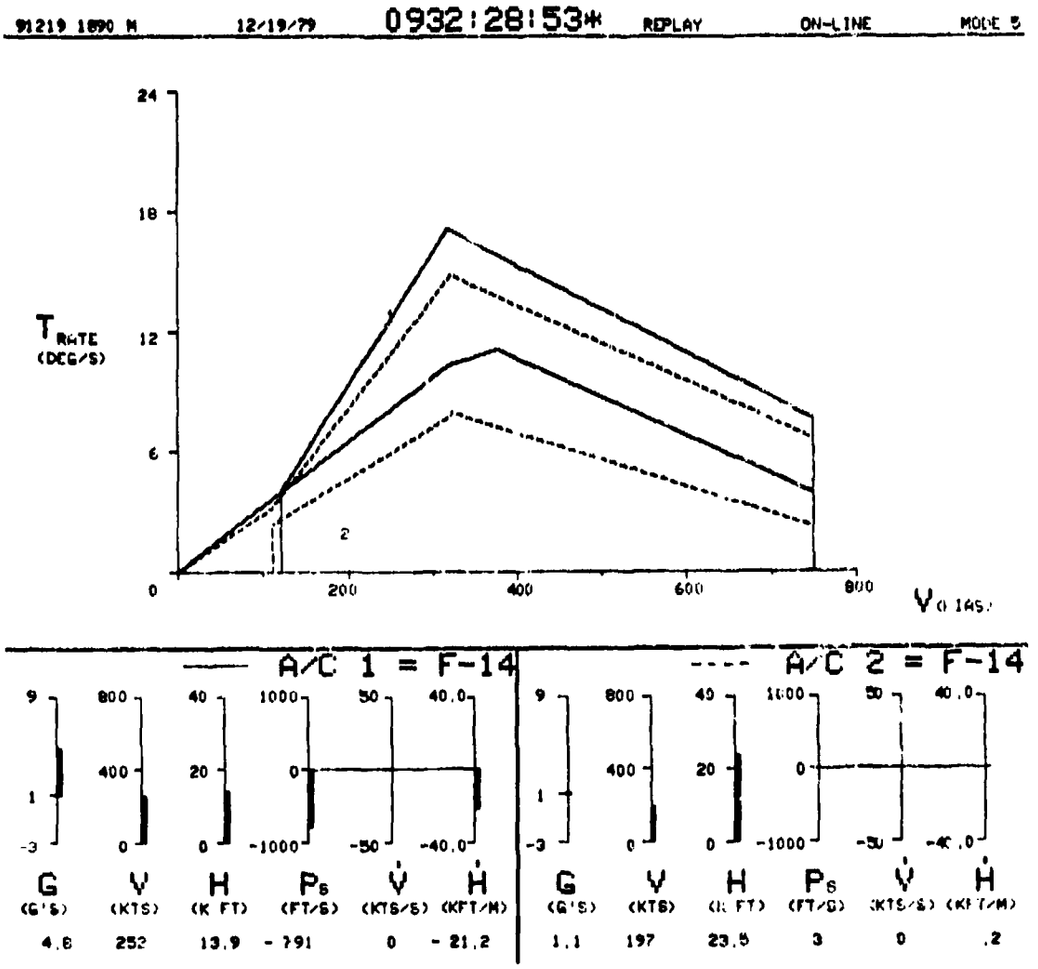
[5]Pruitt, V.R. Energy Management Training Aid for the Navy's Air Combat Maneuvering Range (ACMR). (Technical Report N00123-78-C-1371), St. Louis, MO: McDonnel Douglas Corp., April 1979.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ON-LINE
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24
18
12
6
0
200
400
600
800
T RATE (DEG/S)
V (KIAS)
2
A/C 1 = F-14
A/C 2 = F-14
G (G'S) V (KTS) H (K FT) Ps (FT/S) V̇ (KTS/S) Ḣ (KFT/M)
4.8 252 13.9 - 791 0 - 21.2
G (G'S) V (KTS) H (K FT) Ps (FT/S) V̇ (KTS/S) Ḣ (KFT/M)
1.1 197 23.5 3 0 .2

APPENDIX D

AIR COMBAT MANEUVERING TERMS

ACM	--	Acronym for Air Combat Maneuvering
ACM State	--	A descriptor of the ACM situation as offensive, defensive, and neutral positions
AB	--	After Burner
AIM	--	Air Intercept Missile
ALT	--	Altitude
AOA	--	Angle of Attack
AOT	--	Angle Off Tail; angle between longitudinal axis of target and line of sight from target to fighter in wing plane of target aircraft, measured in degrees.
ATA	--	Angle between longitudinal axis of fighter and target aircraft, measured in degrees (pointing angle).
Bogey	--	A term applied to an ACM opponent (suspected unfriendly or adversary).
Bugout	--	Aircraft leaving arena of engagement or attempting to terminate fight (i.e., escape from Bogey).
Contact	--	A call made by an aircrew member (pilot or RIO) upon obtaining radar contact with a target.
CRT	--	Cathode Ray Tube
DDS	--	Display and Debriefing System

Defensive	--	An engagement state in which a particular aircraft is in a threatened position according to specific mathematical rules.
EMD	--	Energy Maneuverability Display
Energy	--	Kinetic and potential energy state of aircraft engaged in air-to-air combat; can be defined in terms of IAS and cornering trade-off (kinetic), fuel state and altitude (potential).
Engaged Fighter	--	A fighter whose primary responsibility is to kill or control bogey. It should be in an offensive position.
Envelope	--	Weapon boundary limits within which a missile or guns should be fired. An envelope is defined in terms of distance (range) and angles off tail (degrees) between shooter aircraft and target.
Fox 1	--	Call made by aircrew member (usually pilot) indicating that a Sparrow (AIM 7) missile has been fired.
Fox 2	--	Call made by pilot indicating that a Sidewinder (AIM 9) has been fired.
g	--	Normal Acceleration, measured in units of $g = 32.2\ ft/sec^2$.
GCI	--	Ground Control Intercept
IAS	--	Indicated Airspeed; airspeed for aircraft measured in knots.

Lock-on	--	Electronically locking the radar system on a particular target.
Neutral	--	An engagement state in which a particular aircraft is in neither an advantaged or disadvantaged state, according to specific mathematical rules.
Offensive	--	An engagement state in which a particular aircraft is threatening an opponent (see above defensive, neutral).
1v1	--	An engagement involving one friendly versus (v) one bogey aircraft.
PMI	--	Performance Measurement Index
Range	--	Distance in feet or nautical miles (n.m.) between fighter and aircraft.
RIO	--	Radar Intercept Officer
RTO	--	Range Training Officer
SEAM	--	Sidewinder Extended Acquisition Mode
Section	--	Two aircraft that fight as coordinated unit in an air-to-air engagement.
Tally Ho	--	A call made by an aircrew member upon obtaining visual contact with a target.
2v1	--	An air-to-air engagement involving two friendly aircraft versus (v) one bogey aircraft.
2v2	--	An air-to-air engagement involving two friendly aircraft versus (v) two bogey aircraft.

UHF	--	Ultra High Frequency communication channel for radio transmission between aircraft.
Vc	--	Closing Velocity, positive or negative, between fighter and target aircraft, measured in knots.
VTAS	--	Visual Target Acquisition System (helmet mounted gunsight used to slave and point weapon seeker).
Wingman	--	Second aircraft in flight section. Also referred to as "wingy." See definition for "Section."

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